CHALMERS

eZIN

Development of a future electrical bicycle for the ageing population

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Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

Department of Product- and Production Development
Division of Design & Human Factors

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Abstract

A rather important trend for modern society is the fact that average life expectancy is increased with accelerated pace. Furthermore, the burden of lifetime illness is compressed into a shorter period before the time of a person's death, a statement known as compression of morbidity. As a result, people are capable of being more and more active for longer periods and older ages. Considering as well, the fact that most jobs currently, and most likely in the future, involve a lot of office work sitting still, the need for daily exercise becomes critical in many aspects, especially at older ages. Biking can bring these facts together since it can be easily integrated into everyday living as transportation mean. At older ages though, conventional bicycles can present usage requirements and side effects that will prevent people from using them. Electrically assisted bicycles, known as Pedelecs, can help overcome a significant amount of negative side effects of conventional bicycle riding and result in more frequent bicycle use either that is for commuting or leisure purposes. The purpose of this thesis work will be to examine the market and the older aged group specific needs and present a Pedelec design that will attract them into bicycle riding. By doing so, people in specific, and societies in general will benefit from an improved well-being.

The project followed a model called the Vision in Product design or, ViP. The model is especially good for a future context with an existing product, which is the case of the project at hand. The model consists of two phases, the deconstruction of the existing situation and then the construction of the future situation.
The deconstruction phase is about analyzing and breaking down the existing product qualities, product interaction and context. In this phase a significant amount of information was gathered on technology, manufacturing, rules and regulations, infrastructure and of course the target group.

In the construction phase, what is to be offered was thoroughly defined before developing the product. Additional research was made to fill the gap of future technology as the ideation of solutions was made. The visual expression of the Pedelec was an important part of the bicycle's design . The expression was defined, the form generative process was conducted and after a series of evaluations and iterations the final design was decided.

The final product compensates for many of the age related impairments, beside the obvious physical ones, that the ageing demographic is experiencing today by heightening their situational awareness. The design of the bike has an inviting expression by being exciting, simple and capable. Most of the technology is integrated in the frame and is not visible, making the product less complex visually, something that was considered a big concern of the target group.

Preface

This report presents a Master's thesis project of 30 ECTS for the Master's program in Industrial Design Engineering at Chalmers University of Technology in Gothenburg, Sweden. The project was carried out from January 2015 to June 2015.

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Table of contents

1 Introduction 1
1.1 Background 1
1.2 Project aim 1
1.3 Project goal 1
1.4 Delimitations 1
1.5 Project and report outline 2
1.6 Execution and methods 5
1.6.1 Deconstruction phase 5
1.6.2 Construction phase 6
2 Prestudy 9
2.1 Bicycle background 9
2.2 Electric bicycle background 11
2.3 Pedelec background 14
2.4 Definition and EU regulations 14
2.5 Trends and statistics 15
2.6 Electrical bicycle use in the world 16
2.7 Numbers and trends in Europe 16
2.8 Numbers and trends in Sweden 16
2.9 Target group related 17
2.10 Sustainability 18
3 Existing product 19
3.1 Comparison of products 19
3.2 Market analysis 21
3.3 Experience 22
3.4 Retailer findings towards existing product 23
3.5 Price range 25
3.6 Frame types 27
3.7 Drive systems 28
3.8 Battery types-technology 30
3.8.1 General 30
3.8.2 Functionality 31
3.9 Power supply 32
3.10 Deconstruction of product qualities 32
4 Existing interaction 35
4.1 Riding postures 35
4.2 GERT-suit 36
4.2.1 General information 36

4.2.2 Experiencing the target group 37
4.2.3 Testing day 38
4.2.4 Findings 38
4.3 Deconstruction of product interaction 40
5 Existing context 41
5.1 Retailer findings towards existing context 41
5.2 Target group 42
5.3 Interviews with target group 43
5.4 Persona 43
6 Future context 47
6.1 Domain 47
6.2 Context factors and structure 47
6.2.1 Demographics 48
6.2.2 Infrastructure 49
6.2.3 Battery technology 49
6.2.4 SWOT 50
6.3 Production and cost 52
6.4 Statement 52
7 Future interactions 54
8 Future product 55
8.1 Constructing a Theme 55
8.2 Ideation 56
8.3 Focus group 56
8.4 Product qualities, features 57
8.5 Evaluation and iteration 58
8.6 Form development process 61
8.6.1 Quantifiable structure 61
8.6.2 Topological stage 63
8.6.3 Typological stage 64
8.6.4 Morphological stage 65
8.7 Computer modeling 68
8.8 The final design 69
9 Discussion 75
9.1 Final result 75
9.2 Execution 75
9.3 Future scenario 76
9.4 Market introduction 76
10 . Conclusions 77
References .....
Appendices .....

1 Introduction

1.1 Background

The project was initiated by the project participants since a gap was found in the market of electrically assisted bicycles of today. The gap offered an opportunity to develop an electrically assisted bicycle, a Pedelec, adapted to an ageing demographic which today is a large consumer and user group. The product will be developed for use in a near future scenario to see how it will affect individual transportation.

1.2 Project aim

The project aim is to develop an electrically assisted bicycle for a target group which presents age related impairments. The product is to help people with age related impairments to transport themselves individually and independent of other people. The bicycle is to be developed for an urban environment in a future scenario of 5 years and fit the development of technology accordingly.

The aim will be accomplished by answering these specific questions:

- The bicycle has a long history and many things have been developed and tested already, how does this affect new development?
- Which age related impairment matter the most when riding a bicycle?
- Which age related impairments need to be compensated for when biking?
- Which is the desired product expression for the relevant product and target group?
- Which is the future bicycling scenario and how does this affect the design of a bike?

1.3 Project goal

The goal of the project is to help people with age related impairments or similar get active and independent. This will be achieved with an electrically assisted bicycle which compensates for the age related impairments affecting all people at a certain age. The deliverables will be specifying needs and functions of the Pedelec as well as the design of the Pedelec in a computer made model. Parts needed for evaluation will be printed in a 3D printer and checked for functionality as a proof of concept.

1.4 Delimitations

The project is limited by its scope, how age related impairments affect bike riding and how it can be compensated with a Pedelec as well as the target groups wanted expression in the product. The EU's definition of a Pedelec (described later in the report) will be used and seen as the same in a future scenario. There is no reason for a change in the regulation in the future which would affect the outcome of this project.

The project will focus on the physical and mental impairments that are related to a biking situation as well as the functionality and expression of the product. Some aspects of a bicycle will not be investigated and developed further such as seat, rims, tires, fenders or rear rack. The main focus of the design will be the frame and handlebar and things found necessary such as lights, bell and similar.

The electrical system is not designed in this project as it requires a deep analysis and is not necessary for the functionality of the concept, as well as the exact layout and internal construction of motor and gear system.

The product is to be designed for and urban environment for the purpose of commuting and everyday travel and the cost of producing the final product will not be investigated in depth.

1.5 Project and report outline

To tackle the fact that the product is to fit in a future scenario and that most of the information can be gathered about the future situation today a method to work by was chosen that would fit this approach. The model used is the ViP, which stands for Vision in Product design and was developed by Paul Hekkert and Mattias van Dijk. It is meant to be used when working with a future scenario while having as an informational base an existing scenario, existing products and interactions. The philosophy of the ViP method can be described in the following sentences:

“A product is a reflection of the interaction people have with it” and “Designing is about exploring what is possible tomorrow instead of solving the problems of today”

In the method presented by them, the mean/product, with which the project’s goal is reached, should remain completely open until all factors have been considered. In this project the mean of transportation was already chosen, the electrically assisted bicycle defined as the Pedelec. Therefore, some measures were added to fit the project and some aspects of the method were slightly modified. With this said, a condensed walkthrough of the method follows.

The model consists of two main phases, the deconstruction phase and the designing phase. The deconstruction phase is in essence the research phase, where most of the information needed for the project is gathered. The focus is on existing products, interactions and context.

After analyzing the current state of products, interactions and contextual factors in the deconstruction phase, the next step is to define a broad future scenario. It consists of three stages with a total of eight steps and measures to reach the final goal (Figure 1). In the project step seven and eight were combined and therefore the designing procedure has a total of seven steps.

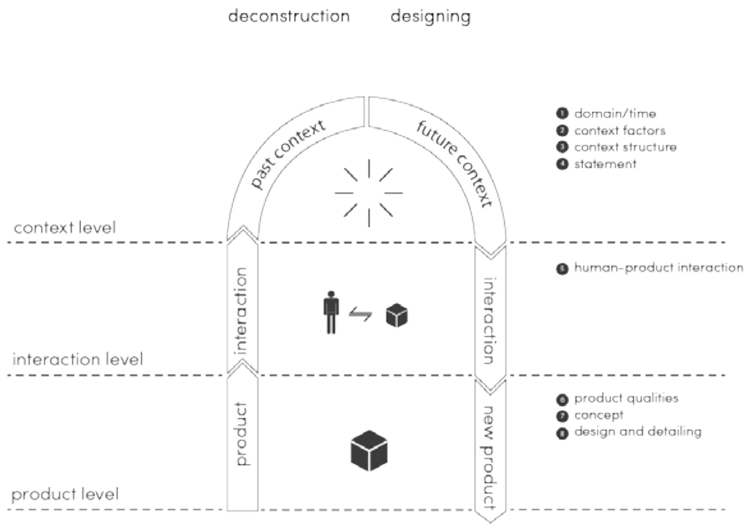


Figure 1. The ViP method

First stage Future context
a. Establish the domain
b. Generating context factors
c. Structuring the context
d. Statement definition

Second stage Future interaction
e. Establishing the relationship of human-product interaction

Final stage Future product
f. Defining product qualities
g. Concept, designing and detailing

a.
Establishing the domain is about describing the area where the project aims to make a contribution, it shall be loose enough to explore different options, but specific enough to make it possible.

b.
Generation of context factors is about building the future world by putting together anything that builds the whole. Factors should only be added if they can drive the concepts in interesting directions.

c.
Structuring context is simply a structuring procedure of the common-quality factors which make up the context so a graspable and easily over viewable context can be provided.

d.
The statement definition is the first big step in creating the vision of the product in the future context. It defines what is to be offered to the intended user without in any way describing how it will be achieved.

e.
Establish the relationship refers to how the product is used and experienced, what value or meaning arises from the relationship between the user and product. The product is just a mean to accomplish the statement. Together with the statement the interaction defines the what and how it will be offered to the user constituting the product's meaning.

f.
Defining product qualities is the last link between the major stages of the ViP. The product qualities will not give the final product. Product qualities can be of two kinds; qualities that express product character and qualities about how the product is used or operated (Hekkert, P.vanDijk, M. 2011).

g.
In concepting, designing and detailing stage all the information from the above mentioned stages are formed into concepts and eventually lead to the final product. Here all factors considered to come into play to shape the final product.

Except what is described in the ViP an evaluation with iterations is placed in the last two stages. After defining the interaction and product qualities the initial concept is to be evaluated and then iterations are made, before the final design phase is started.

The authors of the ViP method suggest to keep a scope as open as possible during the whole development process. This means that the method is designed for deciding what product to design in order to fulfill the statement, interaction and product qualities in the very end of the project. In this project the Pedelec is the aim all along. The investigation process is kept open and broad in the bicycle segment. Vision in Product design implies that the outcome of a process following this method is visionary; this is not the project participants' view though. For them the visionary part is glimpsing into the future and designing a future oriented product according to the future context and environment.

1.6 Execution and methods

1.6.1 Deconstruction phase

Information search (infrastructure, technologies, material, manufacturing). In order to establish a solid foundation on required knowledge for initiating the project, an extensive information search was executed. Throughout the project's duration and mainly during the starting stages, the information intake was evident. Data collected was drawn from variable contexts like interaction, product qualities, historical data, cycling infrastructure etc. Multiple informative means were used, as for example literature studies, the internet, observations and experiences. Information search is an integral part of any project type and therefore the current one as well.

Market analysis. Is the process of gathering, analyzing and interpreting information about a market, or more specific, about a product (Entrepreneur, 2015). It provides significant information on the importance of individual features, costs and other specifics. This information can be analyzed further to discover potential opportunities within the market or position the product among the market's competitors. Despite the project being aimed towards a more theoretical approach since it aims to achieve specific targets within the context of user product interaction, market specifics cannot be neglected. The product is to be produced and accepted in the market and so, it must present competitive advantages in respect with the competition, therefore the need for a market analysis exists.

Experience. Definition of the word experience could be described as '(the process of getting) knowledge or skill from doing, seeing, or feeling things' (Cambridge, 2015). As a method it relates exactly to the same meaning. Getting involved in riding for example an electrically assisted bicycle would be the best way for a researcher to gain related information. Experiencing was used within the project in many ways. An extensive variety of conventional and electrically assisted bicycles were ridden and analyzed in detail. In addition, the project's team members experienced not only the products within the specified market but the actual target group as well. This was made possible with the use of an aging simulation suit described in detail next.

GERT suit. It could be described as a method within the context of experiencing but due to its high importance for the project it will be referred as a different method. The age simulation suit provided to the evaluators the ability to gain firsthand experience on bicycle commuting from an older person's perspective. Being able to instantly change from the state of a physically able person to a physically impaired person gives extensive input to the evaluator and it was the main reason for using it.

Weighted Objectives. The Weighted Objectives Method is an evaluation method for comparing design concepts based on the overall value of each design concept (van Boeijen A. et al., 2013). In many critical stages of the project the method was used to pinpoint the best solution out of a series of alternatives. Early in the project's progress where verification of a solution was needed as well as in later stages where choosing a concept was crucial the method was able to provide well structured solutions.

Interviews. There are several ways to structure an interview and in this project semi structured interviewing were deemed most effective. Since much data can be found in other sources the qualitative answers and discussion were most interesting in. The topics to discuss are decided before the interview and there are some questions to get answers to, but the results found in a free dialogue is most interesting (Osvalder, Rose & Karlsson, 2010). Here there is time and opportunity to ask follow up questions that will deepen the understanding. For all the interview structures pilots were carried out as a testing of the structure and making sure the interviews elicited the needed information.

KJ-analysis. Otherwise known as an 'affinity diagram', KJ analysis is a well known tool used for organizing ideas and data. Each idea is expressed as a single simple phrase and is noted on a card. Related ideas are sorted into groups until all cards have been used. Each group is titled with a header that summarizes the essence of the group and if it is required large groups can be further analyzed into smaller subgroups. The method was used to organize acquired data which due to their big volume were difficult to work with. Interviews with retailers and user groups were falling into this category due to the large data volume produced from the open questions used.

Focus group. The focus group is made out of five individuals discussing and ideating around some predetermined questions or statements. One moderator presents material and relevant information from which the participants first have a short individual ideation session and later they share their ideas, thoughts and solutions to the presented question/problem/statement. The advantage of using a focus group is that it is resource effective when compared to fewer persons performing. The major advantage is the associations the participants make when another participant describes or discusses a solution/problem and the discussion thrives. The focus group also gives a multifaceted perspective to solutions and problems that has to do with the desired subjects (Osvalder, Rose & Karlsson, 2010).

SWOT Strengths-Weaknesses-Opportunities-Threats. A structured planning method used for analyzing in a systematic way the strengths, weaknesses, opportunities and threats involved in a project. Strengths and weaknesses are referred to internal factors and Opportunities and Threats are referred to external factors. SWOT analysis was used in defining the search areas within the future context that could present interesting ideas for product innovation.

1.6.2 Construction phase

Brainstorming. It describes a specific approach with rules and procedures for generating a large number of ideas. It is one of many methods used in creative thinking, based on the assumption that quantity leads to quality (van Boeijen A. et al., 2013). Since brainstorming is beneficial during each phase of the design process it was a method that was excessively used throughout all stages of the project.

Evaluation. An evaluative procedure can be described as a method 'to judge or calculate the quality, importance, amount, or value of something' (Cambridge, 2015). During the project's duration multiple evaluating procedures were initiated with the form concept evaluation been the most distinct. The specific evaluation was performed during the final stages of the project to identify if the produced concepts were in line with the defined wanted expression stated in the theme. For that reason, semantic differential scales were used to provide an easy platform onto which the participants could state how they perceived the coherence between the constructed theme and the proposed concepts.

Personas. Individual, fictional accounts of user group profile data (Lidwell W. et al., 2010). Personas are useful in considering the goals, desires, and limitations of product buyers and users in order to help in guiding decisions about a service, product or interaction space such as features and interactions. During the project three personas were used that were reflecting on the attributes of the target group. Information from the interviews was mostly used to synthesize the fictional characters.

Theme. Is used as a representational summary of the aimed product expression. All gathered information is concentrated and expressed as a single word description that is further analyzed by three helping adjectives. These adjectives are then used to extract form related drivers which constitute the base of the product's concepting phase and are accompanying the continuing form development.

Quantified structure, functional surfaces and banned areas. Quantitative structure and functional surfaces is a method used in form design (Tjalve, E. 1979). After defining how the elements shall be arranged in relation to each other and its functional relationship to the surroundings, the quantified structure is defined. The functional surfaces are the next step in the form development process. By sketching the functional surfaces the surface which has an active function, such as the slot in a screw or the surface of a chair seat, is defined. This method also includes banned areas, in this case spaces. The spaces, or banned areas, have the same attributes as the functional surfaces except it cannot be obstructed by the structure of the bicycle (Tjalve, E. 1979). The method is conceived with generating alternatives on how to order the surfaces and elements in a design, not how to generate many interesting form concepts. Additional method is needed to generate a vast array of interesting form concepts.

Fish trap method. A form generative process named after its' structure shape which is created by diverging, converging and categorizing the generated ideas (van Boeijen A. et al., 2013). The structure resembles a fish trap where the best ideas are caught. It is a three stage process with the first step being to shape a basic structure as done in the quantified structure described in previous method. Thereafter, a topological generative stage follows, which allows work on the connections between the various elements. Many different varieties are evolved and categorized in order for the most interesting topological concepts to be taken to the next stage. Concept feasibility is not considered in these initial stages. Typological concepts are developed from the topological, taking feasibility into account. Next, the connections are given geometrical form and volume. All the concepts are categorized and the most interesting ones progress further. In the morphological stage manufacturing, material and specific solutions are developed in detail. Here the functionality and materials are considered. The concepts are evolved further till the final concept form is chosen (Muller, W. 2001).

Design format analysis . The design format method is an analysis tool for evaluating visual ingredients of a product. The method is a matrix-based method enabling a structured way of evaluating visual design elements. It gives an understanding of the visual components in the product, based on perceptual significance (Warell, A. n.d). The Design format analysis can be used for analysis or, as base for evaluation, as in this project.

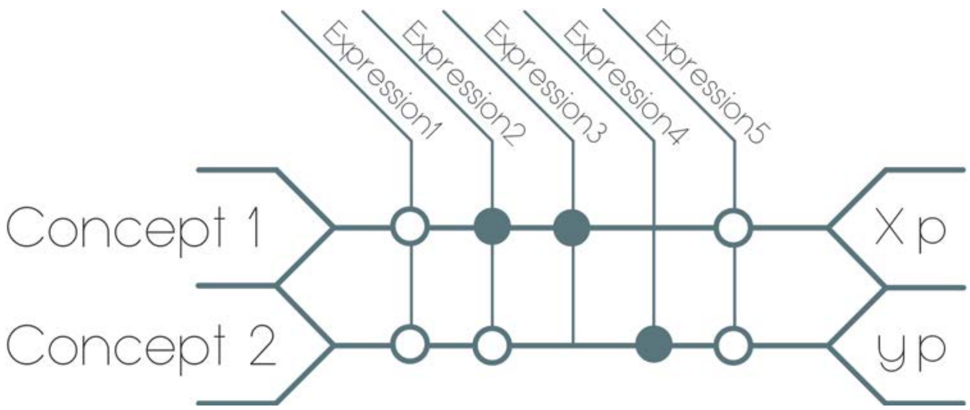


Figure 2. Design format analysis example

The matrix consists of horizontal lines crossed by vertical lines. Form concepts are placed in horizontal lines of the matrix while form drivers derived from the theme are placed on the vertical lines (Figure 2). Where these lines meet a correlation between form driver and concept is evaluated. Rating is performed with a weighted three degree scale from one to three. The score is based on how well the concept fulfills the relevant form driver with one being not at all and three being a good match.

The reason for using the form drivers is that they have been the basis of the form generative process. The analysis is performed at the end of the form development process to evaluate how well the concept fulfills the theme set for the design. The results from this analysis are used as one value in the form decision process.

2 Prestudy

2.1 Bicycle background

In order to be able to examine the principles and specifics of electrical bicycles further knowledge regarding the history of conventional bicycles must be acquired. Throughout its long history numerous developments, approaches and remarks were realized. Having a better view of the details behind the development of the bicycle will make possible the use of former gained experience and past mistakes so they won't be repeated. After all it has been said by the American philosopher George Santayana that "Those who cannot remember the past are condemned to repeat it" (George Santayana, 1905).

The history of bicycle dates back many years. It would exceed the scope of the current project work to refer all the historical facts relating to bicycling development. Therefore, facts and points that have critical importance in bicycling history as well as issues that are believed to be related with the purpose of the future electrical bike will be mentioned.

Bicycle is the most effective medium invented to translate human power into movement (S.S. Wilson, 1973). In 1815 a big volcano explosion caused starvation to global population and horses used in transportation were massively killed due to lack of fodder (Oppenheimer, Clive, 2003). Inventor Baron Karl von Drais, in an attempt to deal with the increased transportation needs caused by the decrease in the number of horses, developed the "running machine" (D. G. Wilson, J. Papadopoulos, 2004). This invention formed the base of what would be characterized at a later time as a 'bicycle" (Figure 3).

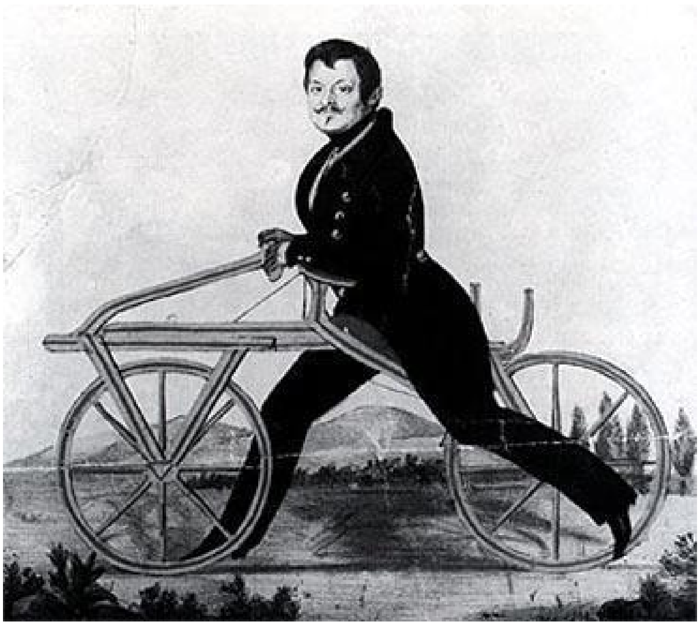


Figure 3. The running machine

Two iron wheels were attached inline onto a wooden frame and the rider positioned the system in between the lower limbs. The front wheel was able to twist to provide turning (something that later on discovered to be the reason for maintaining balance). Therefore, the first ever bicycle patent was created and the product was officially called "le velocipede". It is interesting to note that in England the product was called 'hobby horse' because, in contrast with an animal horse which needs constant treatment and care, it could be left unattended when not in use and therefore it was considered a hobby. Product cost was unusually high and was almost exclusively used by the rich, actually as a hobby product. The two wheeled vehicle could not present its full potential just like any other individual transportation vehicle at the time, because of the rapid railway development. The steamed horses were a far more intriguing technology at the time for users and engineers comparing to the humble bicycle (D. G. Wilson, J. Papadopoulos, 2004).

In the years that followed bicycle products and developments were constantly being introduced and prepared the product to be massively accepted around 1870. Cranks, rubber tires, ball bearings (mentioned as friction rollers) and tensioned wheels with radial spokes were used to enhance the user experience and increase product efficiency. These solutions made possible the use of larger front wheels which were solidly attached with a crank set and by pedaling could cover greater distance per pedal revolution. This lead to the creation of the 'high wheeler' type which dominated the bicycle market around 1890 (Figure 4).

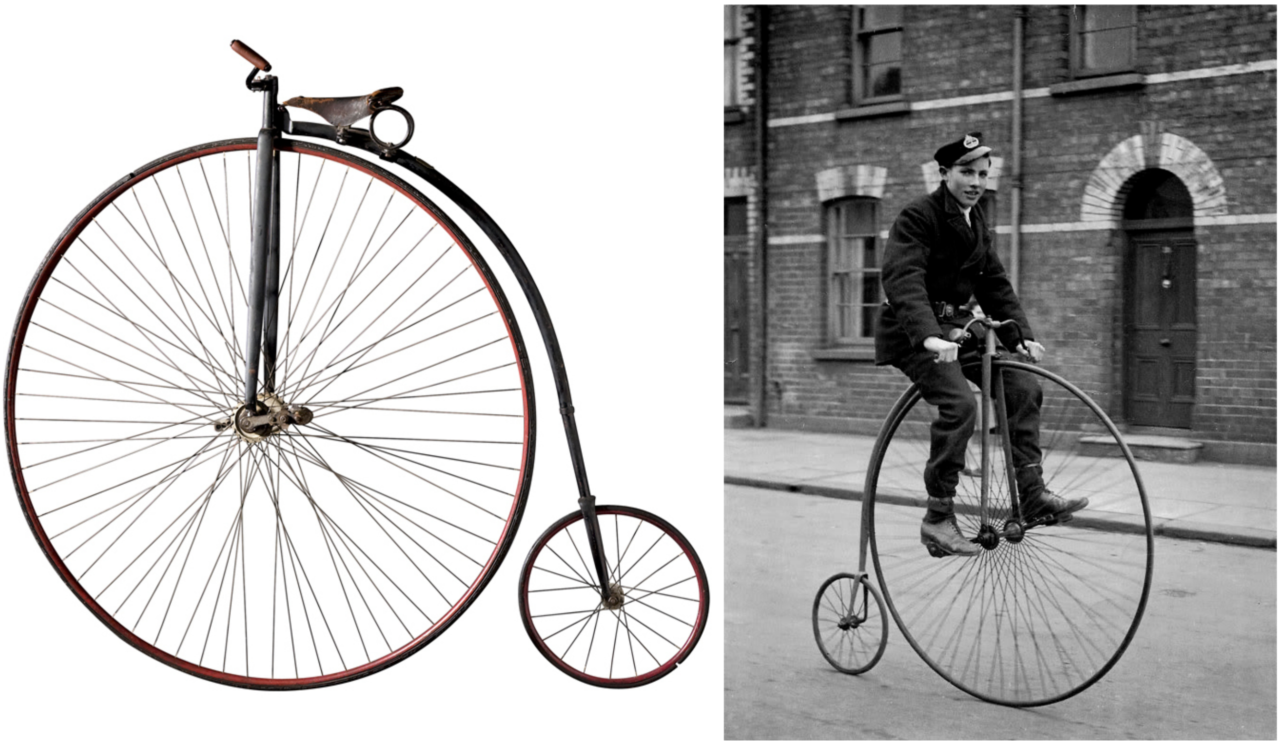


Figure 4. Different types of high wheelers

Again, high wheelers were a privilege of the upper class and especially youngsters. It was a dangerous bicycle to ride since a forward fall was quite common due to the center of gravity being high up, towards the front part of the bicycle and usually had severe consequences to the rider. A need for a safer bicycle was clear and the solution came around 1883 when the first 'safety bicycles' appeared (Figure 5). This bicycle type positioned the rider between two equally sized wheels, had direct steering to the front wheel and a frame that was pretty close to the diamond shaped frames that are used until current times. From that point the main design principle remained the same and refinements of the different parts were realized.

Figure 5. The safety bike

Bicycle usage was still not affordable to working classes and it was some years after the 1890s, when the prices dropped, that they were used for commuting, shopping and weekend travel. During the first world war and due to the restrictions on gas commuting bicycles were on the up, just to face a decrease in use when gas and cars were available and affordable again.

From that point and on the bicycle market was relatively steady. An exception to this situation were the far east countries and especially China where cycling became synonymous with transportation. In the western world though, it was a few years later than 1970 when due to a design competition for human powered vehicles in the US, bicycles surfaced again(D. G. Wilson, J. Papadopoulos, 2004). This rise has lasted until nowadays due to the recent boost in sales that mountain specific bicycles introduced. Bicycles of today incorporate hi-tech solutions in every aspect. Composite and exotic material frames with front and rear suspension, extremely efficient gearing systems, hydraulic brakes and many other innovations are used in top class bicycles today. By improving manufacturing methods and reducing costs these innovations are passed onto every day commuting bicycles used by the masses.

So, the bicycle market has shown throughout the years that bicycles are highly affected on seasonal circumstances. Nowadays, the need for sustainable transportation is acknowledged from society but bicycles cannot offer any further breakthrough solutions towards that direction. Bicycles as products have reached their developmental peak and only minor adjustments brought by new technologies can be implemented. Technology made possible to provide adequate electric energy storage with a reasonable weight which in combination with strong enough motors can magnify the benefits of conventional bicycles. It is history repeating just like when the bicycle formed the base for the development of a long distance travel vehicle, the motorcycle. Nowadays, it is the electrical assisted pedaling bicycle that starts to develop extensively and it would be interesting to see where it will lead people's transportation habits in the near future.

2.2 Electric bicycle background

As mentioned earlier; knowing history prevents people from making the same mistakes. And while bicycle history showed us that some innovations could not present their full potential at the time when they were first conceived, through further technological improvements these same innovations brought big changes to the product. That is describing in a well manner the case of electrical bicycles.

The first electric bicycle appeared in the late 1890s when a related U.S patent was granted. It involved a battery powered bicycle with a 6 pole direct current hub motor mounted on the rear wheel. In 1897, another type of electric bicycle appeared which was propelled by a 'double electric motor'. The position of the motor was placed in the hub of the crankshaft axle and crank rods coupled it with two closely spaced rear wheels (Figure 6). The batteries used were of low voltage, around 10V, and used zinc-carbon acid batteries. These electric machines were based on the 'safety bicycle' and were progressing in parallel since electric bicycle products combined conventional bicycles with an added electric motor.

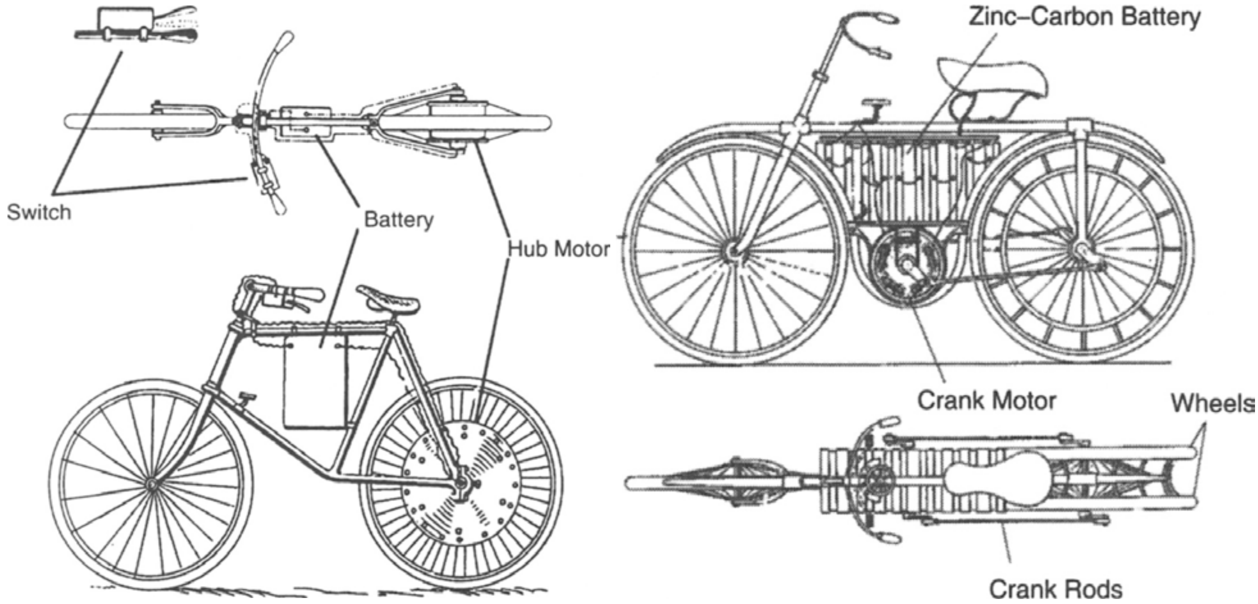


Figure 6.First electric bicycle 1890 and double electric motor bicycle 1897 (from left to right)

At the same time though, interesting innovations and developments were presented regarding the electrical parts and the way they were integrated onto the two wheeled product. In 1898 a driving belt was introduced to transfer the motor power to the rear wheel. The belt went all around the wheel and stayed in place with the help of a tire groove and pressure force created between the tire and the ground. The motor was clamped to the seat post and by rotating a belt pulley attached to the seat stays motion transfer was possible. The following year appeared a design that used a pulley on the motor shaft that delivered motion through friction to the top surface of the rear wheel (Figure 7). The inventor at that time suggested that the battery could be charged by the motor itself acting as a dynamo while the bicycle is moving on a downhill road. It was also mentioned that the battery would still need normal means of recharging. This is the first report of regenerative power as a function for an electric bicycle motor, a feature that is much appreciated in today's electrical bicycles.

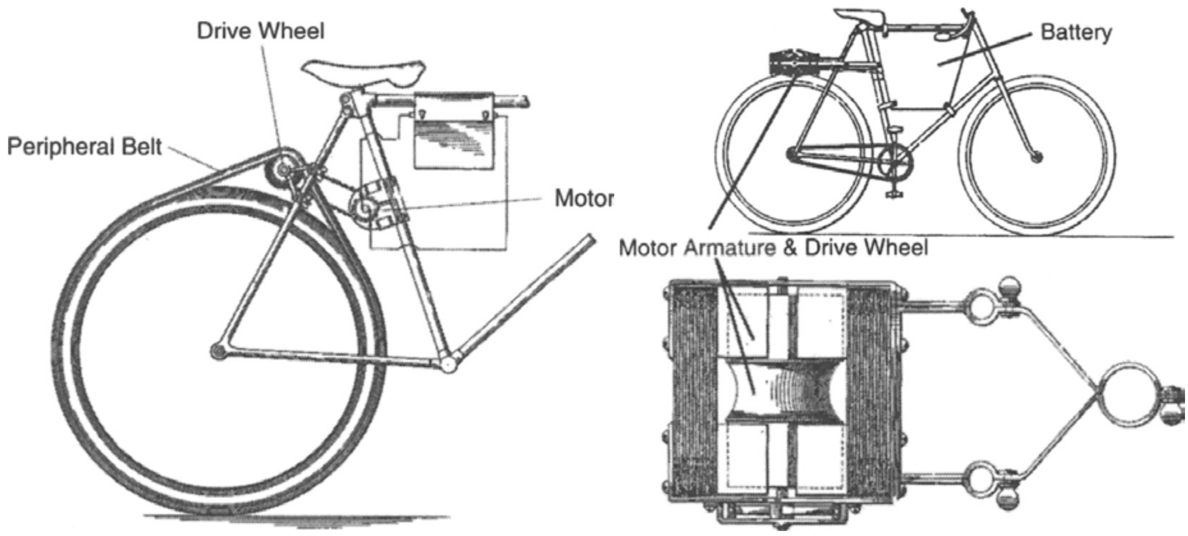


Figure 7. Belt driven electric bicyclein1898 and friction electric bicycle in 1899 (from left to right)

More than a half of century later, during 1969, the friction-wheel principle was expanded further. A series of small electric motors were connected through a drive train to the friction wheel (figure 8). The setup was pulled downwards by a spring to provide the necessary friction between the friction wheel and the bicycle wheel tire. The battery at that stage was still placed in the center of the frame between the rider's legs and the bicycle wheels. In the same patent file of the specific product there is a reference to the benefits of electric motors comparing to other motors used at the time. Other types of motors integrated on bicycles were mostly combustion types and therefore heavy and bulky comparing to the amount of power they were able to produce. Furthermore, considerable noise and gas fumes were produced which forced the rider into experiencing disturbing and rather harmful conditions, facts that are acknowledged at current times as well.

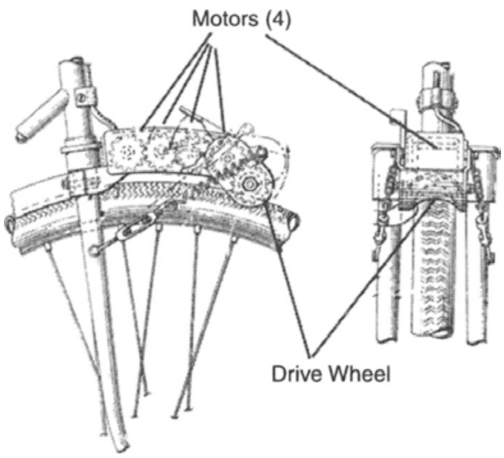


Figure 8. Expansion of the friction wheel principle 1969

More advanced electric motor systems started to use electronics to provide better riding feel and were developed quite recently. Torque sensing and motor power control technologies were developed in the late 1990s in Japan where the first related patents were recorded. In 1989 Dolphin E-bikes designed and produced the first pedal assisted cycle named Dolphin and was introduced in the market from the Swiss company Velocity. Two years later Yamaha started producing large numbers of their version of a pedal assisted cycle under the name of Power Assist. The term Pedelec was first used by Susanne Brusch in her thesis in 1999.

2.3 Pedelec background

Pedelec (**ped**al **ele**ctric **c**ycle) is the term that describes a bicycle that can provide pedaling assistance to the rider through an electric motor. They are considered to be electrical bicycles of small power. The benefits of these vehicle types are multiple. By having extra pedaling power from the motor the rider's mobility is increased significantly. Higher speeds can be achieved and destinations would be reached faster by having a higher average speed with the same amount of effort. Alternatively, same speeds with conventional cycling can be reached with reduced effort. As a result, a Pedelec rider will not reach fatigue limits often and therefore the physical benefits such as reduced sweat levels will occur. Commuting to work can be performed easily without the need of changing clothes or showering. Reduced cycling effort makes longer travels possible so higher commuting ranges can be also achieved. The benefits are considerable for the rider and especially for the ones that commute big distances as well as the ones that do not wish, or do not have the ability, to strain themselves.

On the other hand though Pedelecs bring along with the benefits a series of disadvantages. As a more sophisticated product, purchase cost is considerably higher comparing to a conventional bicycle. The electric and electronic parts as well as some better quality conventional parts that are required for an electric bicycle raise the manufacturing cost around 5 times. In addition, by adding extra parts to the bicycle it gets more complicated as a product and its use is not so straightforward. This fact adds to the aesthetic disruptions that occur due to all the added electrical parts. Most important is the cost of maintaining a Pedelec which includes battery changes every couple of years which is a considerable cost. The downsides though, are of minor importance for riders that will embrace the benefits provided by a Pedelec product.

The terms and conditions under what is characterized as a Pedelec can vary within different parts of the world. A closer look on the European regulation that relates with the licensing and characteristics of transportation means will be performed.

2.4 Definition and EU regulations

The European Union directive 2002/24/EC exempts vehicles with the following definition from type approval: "*Cycles with pedal assistance which are equipped with an auxiliary electric motor having a maximum continuous rated power of 0.25 kW, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25 km/h (16 mph) or if the cyclist stops pedaling.*" Therefore, this statement can form the definition of an electrically assisted pedal cycle in the European Union. Pedelecs are considered conventional bicycles and do not require type approval or driving license. Furthermore, insurance and crash helmet are optional to the rider. The main concern of Pedelec manufacturers is to aid pedaling and therefore, power from the motor is provided only when the rider is actually pedaling.

2.5 Trends and statistics

Electrical bicycle growth is dependent on many factors. Mainly it relies to existing conventional cycling culture and various social behavioral models which can be quite diverse from place to place. It is a bidirectional relationship since electrical bicycles can grow rapidly in areas that present already a high percentage of conventional bicycle use. At the same time, commuter's need for improved transportation means and therefore Pedelecs, will promote growth in bicycling infrastructure.

Cycling culture is referred to places which do actively support a large percentage of cycling done simply as a mean of transport, known as utility cycling. Well known examples include China, Bangladesh, Japan, Denmark, Netherlands, Germany and Sweden. Cycle culture presents a well-developed cycling infrastructure which includes segregated bike lanes and accompanied necessary traffic laws and arrangements. In addition to traffic related infrastructure, extensive facilities catering urban bicycles such as bike racks, public service and pump stations, public transport regulations, do exist to a broad extent as well. Having developed cycling culture means that Pedelec users will be able to take advantage of all the provided benefits. There is no point in increasing the mobility of a transport mean if its use is dangerous, uncomfortable and unpractical.

On the other hand social behavioral models regarding personal social status and sustainability image, socio economic growth and other similar factors affect Pedelec market penetration. Cars as the main competitor to Pedelecs for small distances are currently pushed out of inner urban areas. This process will probably be accelerated by the constantly increasing number of active Pedelecs and higher percentages of public transportation usage (GoPedelec!, 2012). In addition, increased presence currently of pedal assisted bicycles will bring a realization of their true usage potential. Currently, the product is only seen as a bicycle that is easier to pedal and therefore people cannot realize the increase in mobility that can be offered. Pedelecs are not only referred to older people with physical disabilities but to other target groups facing new experiences. Having assistance on pedaling allows for products that can carry up to 100 kg and that means that grocery shopping is performed in an easier manner, just like it would be easier bicycling with children been transferred on the cargo space of a cargo bike. Therefore, despite the fact that currently the majority of Pedelec owners are older people, eventually younger aged users will also appreciate and embrace the product.

These trends are clearly visible in the latest statistics provided by officials. “In addition to new technologies, economic and environmental market forces are also shaping the global e-bicycle industry. Governments are offering support for sustainable transportation, while consumers are finding value in this alternative mode of transportation as a way of avoiding traffic and high fuel prices, and navigating congested urban areas.” (Navigant research, 2015). The numbers of Pedelec sales during recent years show that pedal assisted bicycles are gaining ground over conventional cycle use. Last but certainly not least, same statistics show that the average value for acquiring a Pedelec increases constantly.

Having knowledge over past statistical information will be beneficial in predicting future values related with the context within the project’s product is to be operated in. Therefore, a more detailed research towards statistical data was realized and is presented further on together with general information related with electrical bicycle usage.

2.6 Electrical bicycle use in the world

Globally there are three major bicycle markets with different characteristics, eastern Asia, Europe and Northern America. Eastern Asia and more specific China, was and still is the leading electrical bicycle market. Despite the bicycle been invented in Europe, China managed not only to adopt its use, but in a relatively short period of time lead its manufacturing. Around 1930 China established a domestic industry for bicycles which caused succeeding product price cuts. As a result bicycles were slowly increased in numbers and spread geographically, especially after the foundation of the People's Republic of China and its subsidies to the cycle industry and users(Esfehani, A. M., 2003).

Although the electric bike appeared in China in the 1960s, it did not emerge into the market until the late 1990s (Weinert JX et al., 2007). Starting in 1998, despite the dramatic reduction in traditional bicycle use, the electric bike began to grow rapidly (Cherry C., Min H., 2010). The output of electric bikes in China increased from 30,000 in 1998 to 30 million in 2010 and is expected currently to exceed 40 million units (EBWR, 2013). Electrical bicycles in China are used mainly as cheap alternatives to cars and other fossil fuel competitors, especially since motorcycles and mopeds were banned in 2009 from the majority of China's big cities (Chi-Jen Yang, 2010). Both Pedelecs and throttle controlled units are being used with the majority of them being electrical bicycles with powerful motors that would not be classified as Pedelecs in Europe.

2.7 Numbers and trends in Europe

Second largest, with a significant value difference, electrical bicycle market is the one in Europe. Western and central EU countries have developed a respectable bicycle infrastructure and culture and in some places bicycle usage is an integral part of everyday life. Countries like The Netherlands, Denmark and Germany present high bicycle usage rates that in some cases reach up to 25% of all travelled distances. Due to the fact that in most European cities the foundation for implementing bicycles in everyday living are concrete, electric bicycles flourished in booming rates. 2012 was the first year that Eurostat was able to monitor imports of electrical bicycles so a clear view of the market could be achieved. The numbers showed that there was an average yearly increase around 15% during years from 2010 to 2012. Currently over a million e-bikes are sold in Europe annually which is a huge increase comparing to 300.000 sold units in 2008. Forecasts predict that e-bikes and more in specific Pedelecs will continue to grow in numbers. This increase will be performed over the use of conventional bicycles and cars. People and authorities realize more and more the benefits of Pedelec usage and they are expected to adopt and promote their use respectively.

2.8 Numbers and trends in Sweden

Sweden has a long bicycle tradition and at the moment is one of the highest ranking countries when it comes to bicycle usage since 20% of all Swedes use a bicycle every day (Cykelsmart.se, 2014). In most of the country, biking infrastructure is adequate and is constantly improving. Historically Swedes are buying their bicycles for commuting purposes and not so often for sport and recreation despite the fact that during summertime 44% of the population is using the bike as an exercising tool (Cykelsmart.se, 2014). High bicycle commuting rates, like 28% of all Swedes use a bicycle for commuting at least once per week (Cykelsmart.se, 2014), make perfect ground for Pedelec growth. The standard bicycle which incorporates an internally geared rear hub is the bestselling bicycle type. Recent years hybrids have entered the market and have taken market share from traditional bicycle types. Total number of bicycles sold in Sweden during 2014 were estimated to 575,000 units which presents an increase over the previous year of 3,5%. Imported e-bikes were about 19,000 in 2014, again increased by an impressive 79% over 2013. If local produced Pedelecs are added then the use percentage of electrically assisted bicycles is increased even further. Brands like Ecoride are specialized in Pedelec production while other conventional bicycles manufacturers, like Crescent ,Nishiki and Skeppshult have already added Pedelecs in their product lines.

2.9 Target group related

The target group expands in the future and it is relevant to look at the health of the target group as well. There is a concept called compression of morbidity which refers to that the time before the first marker of morbidity (first heart attack, first dyspnea from emphysema, first disability from osteoarthritis, first memory loss of a certain magnitude) increases faster than life expectancy (Fries, F-J. 1982) (Figure 9).

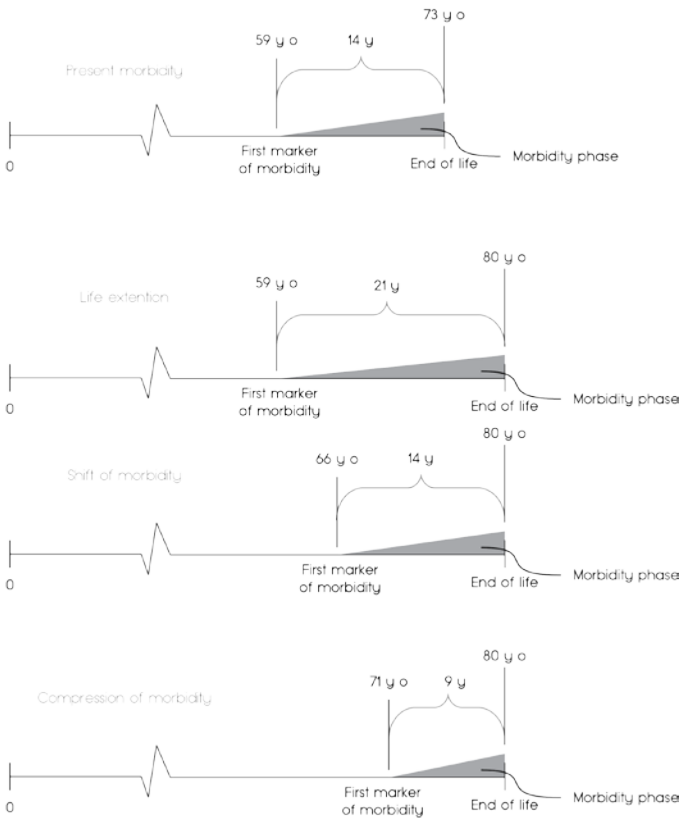


Figure 9. Visual representation of 'Compression of morbidity'

This can be achieved by a healthier lifestyle with exercise (Hubert, HB et.al. 2002). More exercise would aid compression of morbidity, which makes people capable to transport themselves on a bicycle for a longer period of time.

2.10 Sustainability

The project's main goal is to motivate older people get physically active through the use of a transportation mean that promotes, amongst other beneficial behaviors, sustainability. As a product, the bicycle is ranked in sustainable value, second right after walking. If distance covered is considered as an evaluating factor then it is considered as the most energy efficient transportation mean. Unlike its fossil fuel competitors, bicycles do not produce any gas emissions and their carbon footprint which is referred mostly in the energy consumed during their production is kept on a very low level. In addition, bicycles eliminate fossil fuel dependence as well as the need for extensive infrastructure required for heavier and bigger sized vehicles.

In the case of a Pedelec, under certain circumstances sustainability values are even higher when compared with those of a conventional bicycle. A Pedelec has a bigger carbon footprint since it is slightly more complex to manufacture. It uses parts which require considerable energy amounts for their manufacturing, battery and motor being the obvious ones. On the other hand, if travelled distance is considered in the sustainability evaluation, Pedelecs score very high. Assistance motors used in Pedelecs are extremely efficient while the energy used is multiplying the travelled distance in such a well manner that the increased carbon footprint is quickly counterbalanced. The effect is more evident especially if the Pedelec is used as an alternative to a transportation mean using an internal combustion engine.

In many ways Pedelecs are already quite sustainable products which promote a corresponding behavior. Even though, throughout the project sustainability will be considered as a factor for general decision making in designing and manufacturing so that the future product will score even better.

3 Existing product

3.1 Comparison of products

Future societies will have to accept the constant increase in both conventional bicycles and Pedelecs and the question that rises is whether these transportation means will form the optimum way to follow towards a healthier and more sustainable future society. Therefore, bicycles and Pedelecs were compared against their current and possible future rivals. The context of the comparison is referred to transportation means that relate to future individual transportation in an urban environment. A series of eleven transportation means was put together, amongst of which conventional bicycles and Pedelecs were present, and rated against a series of weighted factors. The factors were chosen among different areas of interest and they will be analyzed in detail next.

It is believed that in a period of ten to fifteen years, typical human needs towards transportation and human behavior will be very close to what is noted today. Therefore, the four categories that describe each transportation mean are “social effect”, “efficiency”, “cost” and “self fulfillment”. Each category includes factors that describe in the best possible way the respective category and will be discussed later on. In addition, each factor is rated in a scale from 0 to 9 with 0 being the minimum and 9 being the maximum rating within the rated means. Ratings in most cases characterize each competitor both when in actual use and also while being stationary.

Examining in detail the different categories, social effect is referred to the impact of use each transportation mean brings to society. The factors that describe it are 'silent operation', 'low emissions' and 'space efficiency'. It is crucial today, and most probably even more in the future, the impact the competitors have in peoples wellbeing especially within dense populated areas. These factors give existence to major problems which undermine people’s living quality in urban environments. Considering that these problems are increasing constantly due to the fact that people more and more concentrate in urban areas, the comparison weight of each social effect factor is increased. Silent operation refers to the noise levels produced towards the user and the surrounding environment. Emissions are related to gasses and other possible outputs when the product is in use and/or when fuels for its use are produced. As far as the space efficiency factor, it describes the infrastructure volume needed for transporting or storing the transportation mean.

Further to analyzing the categories, it is clear from the number of contributing factors that efficiency is the most extended one. Since the comparison is about a transportation mean it is unavoidable not to include efficiency factors. 'Weather protection' is referred to the protection each competitor can provide from natural elements. 'Traffic safety' describes not only the protection the competitor is providing to the user but the possibilities it offers towards a safer context of transportation. For example cars and motorcycles are using highways and common roads while bicycles and Pedelecs are using bicycle lanes and most often dedicated bicycle roads which are by far safer. In dedicated bike roads, travelling speeds are low and the user-transport mean system constitutes a small volume, providing exceptional visibility. In addition, mass is significantly smaller comparing to a car so serious injuries from accidents are less common. Other factors in this category describe mobility issues like commuting 'Range' capabilities, 'Cargo' carrying capacity and maximum 'Speed'. Also, effort required for commuting with each transport mean is set as an efficiency factor. This is referred both in mental and physical effort and is noted as 'Effortless' to match the other ratings, making walking having the lowest rating.

Cost could not be missed as a comparing factor category. Cost is described by the average amount of funds a user is saving when buying a new transport product expressed as 'Acquisition cost saving' , the expenses required for its maintenance as 'Maintenance free' and the created cost related to a given travel distance as 'Mileage efficiency'.

Finally, the last comparing category refers to self-fulfillment factors. This category consists of the 'Freedom' and 'Sustainability' factors. 'Freedom' describes the possibilities provided for independent mobility. The more complicated the product the more rules and restrictions it is forced to follow. Traffic jams, enclosed environment, highway code, constitute rules and restrictions that can limit the user's freedom. In addition, sustainability matters describe the energy used for manufacturing the competitor in relation to what it can provide.

The comparison table was completed with ratings according to personal knowledge and judgment. To further examine the results from the comparison extra classification was performed according to the rating of each category as well as weighting the factors (AppendixA1). The later was completed according to the needs of the project's target group. Results can be seen on the following table and charts (Table 1).

Category	FEATURE/WEIGHT		ELECTRIC CAR	PETROL CAR	MOPED CAR	MOPED BIKE	ELECTRIC BIKE	PETROL BIKE	ELECTRIC BICYCLE	BICYCLE	TRIKE	SEGWAY	WALKING
Social effect	SILENT	W3	3	2	1	0	4	0	6	7	7	6	9
Social effect	LOW EMISSIONS	W5	5	0	3	4	6	2	7	9	9	7	9
Social effect	SPACE EFFICENCY	W4	0	0	0	6	5	5	7	7	5	8	9
Efficiency	WEATHER PROTECTION	W3	9	9	9	5	5	5	9	9	9	7	7
Efficiency	TRAFFIC SAFETY	W5	7	7	8	4	1	1	8	8	8	8	9
Efficiency	RANGE	W2	7	7	6	7	8	9	5	4	3	3	1
Efficiency	EFFORTLESS	W3	9	9	9	9	9	9	7	5	4	7	0
Efficiency	CARGO	W2	9	9	8	4	4	4	3	2	3	2	0
Efficiency	SPEED	W1	8	8	7	6	9	9	5	4	3	3	0
Cost	ACQUISITION COST SAVE	W2	3	0	1	5	1	3	5	7	7	2	9
Cost	MAINTENANCE FREE	W3	2	0	2	3	3	3	6	8	8	5	9
Cost	MILEAGE EFFICENCY	W3	3	0	1	2	4	2	8	9	9	6	5
Self-fulfillment	FREEDOM	W5	0	0	0	5	5	5	7	7	7	8	9
Self-fulfillment	SUSTAINAB...	W4	3	0	1	3	4	2	7	8	8	7	9
	TOTAL		196	135	162	196	206	166	299	324	312	285	317

Table 1.Transportation means comparison

From the comparison results it is clear that the most suitable transportation mean for small distances within urban areas is the bicycle. Considering the project's target group and all the physical limitations that they might present, Pedelecs present the next best solution and therefore choosing it as the mean that provoke the target group to become active is verified.

3.2 Market analysis

As it was mentioned earlier Pedelec market is increasing rapidly and companies constantly produce different types of Pedelecs to satisfy market needs. Pedelecs as products are combining conventional bicycles with different types of electrical assistance. Conventional bicycle types and parts are numerous just like the available electrical sub systems. Therefore, the possible combinations that could be derived are countless and it is something that is obviously reflected in the current market. Since Pedelec market continues to grow these combinations will be even bigger in numbers in the future. On the other side, Pedelecs have entered the mainstream market during last 15 years. They are still on the up and their development results in interesting bicycle forms and types that are significantly different from conventional bicycles. Pedaling assistance technology, extended Pedelec possibilities and slightly different user pedaling behavior add into having a Pedelec of a different form. Currently, users demand a Pedelec that is similar with conventional bicycles but as more and more Pedelecs are introduced and the market is getting used of the new form more interesting solutions will emerge.

In the following figures a broad variety of electrically assisted bicycles and a small number of e-bikes are observed (Figure 10). The diversity in form, features and specifics can be clearly be noted.

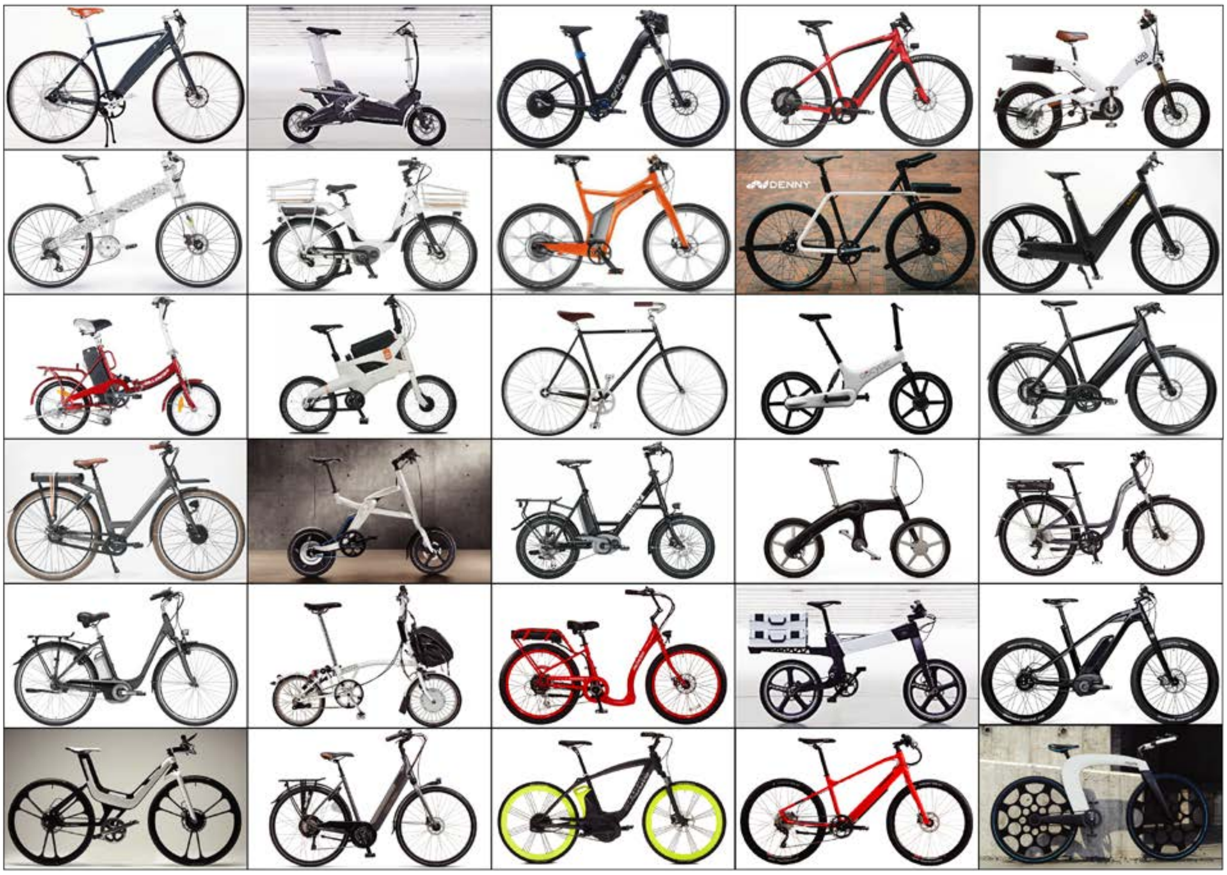


Figure10. Representative ebikeproducts

3.3 Experience

In order to have a better understanding of the feel using a Pedelec a series of actions were taken. Different Pedelec types were ridden and evaluated in bicycle shows in London, UK and in Copenhagen, Denmark. Considerable information was also gathered from the use of a public Pedelec sharing system that is active in Copenhagen named Bycyklen (Figure 11).

Figure 11.'Bycyklen' Copenhagen's public Pedelec sharing system

Tests drives performed in bike shows were the most helpful in understanding the differences between various bicycle types been combined with different pedaling assistance systems. Being able to test ride one Pedelec right after another in a designated test area made possible to distinguish small differences among the products that would be difficult to discover otherwise. The feel of pedaling assistance was the key element in most test rides. In some Pedelecs it was barely noticeable with electronic sensors and appropriate controllers performing in an excellent manner while in other systems it was clear that the manufacturer put no effort into providing a progressive assistance feel. Of course, general product quality was also pinpointed and specific features, which aid towards a better user experience, were noted. Features like robust construction, use of quality materials, automated gearing systems were the ones that made the biggest impression.

Adding all the extra electric equipment to the bicycle resulted in a reduction to the riding sensation especially when compared with a conventional bicycle. Pedelecs feel much heavier since the combination of motor, control equipment and battery add around 5 kilos to the total weight of the bike. This weight and especially the battery which in most test ride cases was positioned on the upper part of the bicycle, is the one with the biggest effect. When positioning the battery on top of the rear rack besides the increased difficulty in control, it’s movement produced significant vibrations. Also, in some cases coasting quality was reduced, due to the use of heavier duty bearings in the wheels that can manage the extra weight efficiently. Besides the heavy duty bearings hub motors added some friction vibration which could be felt into the pedals when the assistance motor was deactivated.

In general, during the tests controlling the Pedelecs felt different comparing to a conventional bicycle. Using a Pedelec will require from the user a period for getting used to. Furthermore, quality observations pointed out that quality levels are not always proportional to pricing. Some of the bicycles tested from the lower to medium price range, were evaluated much higher comparing to other bicycles from the higher price range. Bicycle and Pedelec selling firms nowadays can arrange reduced product costs in many ways. Part suppliers and manufacturers provide different pricing related with production numbers, delivery times and other factors. Also, transportation costs are reduced significantly when it comes to high product volumes. Innovation and research is also a factor that could determine pricing. Costs put into research are expected to be gained back from a slight increase to pricing. Therefore, it could be said that modern commerce ways are defining the pricing to a large extend. Choosing the best Pedelec in relation to its price, for an individual consumer could be a troublesome procedure.

As a result, a consumer will need proper guidance to choose a pedelec product according to individual needs. Currently, since Pedelecs are relatively fresh in the market consumers are not so informed in relation to assistance systems. Pedelec users are in need of answers and explanations to their questions so they will feel more comfortable in buying a Pedelec. Even the contributors of the project, despite all the gained knowledge, were in need of proper official guidance from companies or authorized distributors.

3.4 Retailer findings towards existing product

Especially in the case of authorized retailers introducing or informing the customer, regarding various technologies, is to be performed in an organized and structured way. That is the reason why manufacturers train retailers so they would be able to express the company's targets, the product's specific benefits in relation to competition etc. In addition, retailers are taking in customer needs and requirements in order to be able to offer the best possible solution and to some extend help the company conform to these needs or even better foresee future ones. This is the reason why authorized Pedelec retailers form points where customer demands are gathered. Therefore, to get a better understanding of the market situation multiple interviews were realized with retailers. Interviews were performed in the two biggest Swedish cities, Stockholm and Gothenburg completing one and four authorized Pedelec retailer interviews respectively (Figure 12). A question form was prepared to be used as a guide for a structured conversation with the retailers (AppendixA2). After the end of all interviews a KJ analysis was performed to categorize the results and offer a better understanding of the findings.

The retailers constitute links between the manufacturers and the pedelec product consumers presenting extensive knowledge regarding both sides. In addition, they have personal opinions and their answers need to be viewed critically. The results from these interviews gave an indication of whom the consumer is, what they need help with and what they like in a product. Many things were common between the different retailer interviews and the results are presented in the following text.

Figure 12. Discussing details before retailer interviews

Retailers verified what was obvious from statistics, that Pedelecs are certainly gaining ground over conventional bicycles and other means of personal transportation. What was not obvious from statistics though was the way people are accepting Pedelecs. Retailers remarked that "Most buyers do not want their Pedelec to look electric". This means that the increased number of Pedelecs sold during the later years was achieved solely by the technology of the product and the benefits that can present to its users rather than Pedelecs being visually attractive to customers. After all, almost all Pedelecs currently in the Swedish market are 'electric looking' with cables, motors and batteries exposed visually. In addition, customers seem to have a difficulty choosing a Pedelec with distinct 'electric' character because they are biased by using pedaling assistance while biking.

Additionally, an electrical assisted bicycle integrates details that add to the visual and functional complexity of the product. Extra cables and controls along with other electrical detailing cause purchasing hesitations to customers. It seems that users are mostly troubled regarding the ease of use that Pedelec products might be lacking if compared with a conventional bicycle.

The above two retailer remarks are verified by the fact that people who buy a Pedelec for the second time are increasing their budget significantly. The ease of use is not a matter to consider once a user tries a Pedelec. Retailers also stated that 9 out of 10 people who test rode some 'promotional' Pedelecs end up in purchasing one. Additionally, owning a Pedelec makes easier to realize all the extra benefits that come from its use, reducing hesitations based on prejudgment.

Retailer interviews brought forth other interesting points as well that revealed in turn additional user needs. It was clear that customers who had more experience with various Pedelec types preferred not having the motor in the front hub since it made the bicycle difficult to control. The difficulty was referred both to handling the bicycle while riding and while off the bike parking it or storing it. The weight of the motor affected the center of gravity in a critical area of the bicycle, that of the front fork, producing an awkward riding feel. As for the parking or storing the bicycle, again, the weight of the fork caused the front wheel to turn perpendicular to the bike's length causing instability issues.

Retailers showed specific interest in the use of a carbon belt drive for transferring power from the cranks to the rear wheel. Carbon belt drives present a much lower maintenance rate when compared to traditional chains, without any significant loss in efficiency or reliability, characteristics that are essential to all bicycles and especially to the ones used for urban transportation.

In conclusion, findings from the retailers were:

- Most Pedelec buyers don't want it to look electric
- Cables and components scare people because it adds complexity
- Second time buyers and more experienced Pedelec buyers don't want a front hub motor
- Low center of gravity gives more control and stability
- Carbon belt driver have less maintenance and do not require lubrication but on the other hand needs more work to change

The retailer interviews gave many interesting findings in relation to product qualities. The interviews were conducted in one session in each case. Results were transcribed, printed and put through a KJ-analysis to find common themes from the different interviews. They were divided into product related and context related quotes to be used in the structure proposed in the ViP method. By doing so, context factors were also distinguished between qualities and context. Making this division from the beginning in the KJ-analysis could have led to a bias when analyzing the quotes from the interviews by fitting them in an inappropriate category. Although the method worked well, interesting aspects might have been lost.

3.5 Price range

Within the context of the Pedelec market research a comparison of Pedelec product prices was performed. As it is mentioned earlier, the existing variety in Pedelec products is immense. This is reflected also in the prices of the products. Easily, customers can find decent quality Pedelecs below the 10.000 SEK mark, up to uniquely made products that go over 50.000 SEK. In order to organize the findings towards prices and their relation with Pedelec features, price ranges were introduced. The result can be seen in Figure 13, where 5 price ranges are presented each one through a representative Pedelec model.

Price range

Dillinger Cheetah	Ecoride Ambassador	Batavus Sella E-go	Koga E-special	LEAOS
No name bottom bracket motor	Front wheel motor	Bosch bottom bracket system	ION bottom bracket system	NuVinci bottom bracket system
Single speed	3 or 8 speed	9 speed	9 speed	NuVinci automatic gear hub
Folding Iron frame	Iron frame	Aluminum frame with front and saddle suspension	Aluminum frame with front and saddle suspension	Carbon fiber frame
20Km/h	25Km/h	25 Km/h	25 Km/h	25 Km/h
< 45 Km	< 50 Km	< 135 Km	< 135 Km	< 90 Km
28 Kg	22 Kg	22 Kg	22 Kg	22Kg
3.400 SEK	13.500 SEK	26.900 SEK	33.500 SEK	49.200 SEK

Figure 13.Pedelec price range categories

The lowest price category refers to products that are targeted to achieve small production cost without taking into account the discounts in quality. Frame and bicycle parts are provided from no name manufacturers, lacking performance, warranty and reliability. The prices can start as low as 3.400 SEK and reach close to 10.000 SEK.

Next price range is the most popular currently in Sweden and is referred to products that are provided from well respected local or foreign manufacturers. The electric and mechanical components used are reliable and usually come with a guaranty of good function. It is a big step up in quality level comparing to Pedelecs from the previous price range but still lay in the lower part of the available quality spectrum. Prices for this category are from 10.000 SEK to 18.000 SEK.

As the quality becomes better the price is increasing and that is reflected in the next price category. With a price tag from 18.000 SEK to 27.000 SEK a buyer can purchase a Pedelec with middle to high end quality parts. An interesting point in this category is the amount of options that are presented to buyers. Countless combinations with different equipment, parts and accessories can be achieved. Clients can choose a product according to their specific needs better than any other category maintaining a high ratio for quality versus expense. Usually, basic features like frame material, battery capacity and motor specifications are superior comparing to previous categories.

The overall quality is getting even better in the next price range that is formed out of Pedelecs with cost from 27.000 SEK to 35.000 SEK. Parts used in these Pedelecs are top of the line with respectable warranties. Frames are constructed in such a way so they can accommodate electrical features like the battery or integrate the motor. Basic characteristics though, are not different comparing to what it was offered in Pedelecs belonging to the previous price range.

Finally, the last category starts from 35.000 SEK and reaches up to 55.000 SEK. These Pedelecs present again top quality but they also include additional unique features like composite materials and breakthrough innovative technologies.

These prices reflect the situation of the market at the moment and are expected to change in the future. Prices will still be covering a broad range but as Pedelecs are produced in bigger numbers, parts, manufacturing methods and logistics will be reduced in cost and users will benefit from better quality in the same or even lower price. Considering the fact found in retailer interviews that second time buyers are increasing their budget significantly, it is safe to say that the popularity of the price range will be shifted towards higher cost ranges for Pedelecs that will provide a series of unique features and that will be the price range that the current project pedelec product will target.

3.6 Frame types

Going further into the market research it is clear that besides the price range some categorization of features must be performed. Due to the vast variety of different features in Pedelecs caused by the combination of traditional bicycle parts with the electrical ones, only some basic categorization will be performed. On the side of traditional bicycle parts, frames will be discussed since it is the component that defines to the largest extent the use and character of the bicycle. It is related to the size of the wheels the distribution of the bicycles weight and many other specifics that will be analyzed further on. On the other side electrical parts present the same variability and therefore only some basic system overview will be performed. Combining these two categories is an interesting act since conventional and electrical parts are interacting with each other in ways that were not possible in past times, presenting new and interesting opportunities.

Taking a closer look at frame types used in Pedelecs it is clear that the majority of available options are within the five categories presented in Figure 14. First we find the most popular conventional bicycle frame, the diamond frame. Its structure is based on combining two or more triangles that are known for their mechanically ability to withstand large forces since they are distributing the force load in an efficient way. This provides a frame that is relatively light and stiff. Diamond frames usually make use of big sized wheels that provide smoother and faster riding.

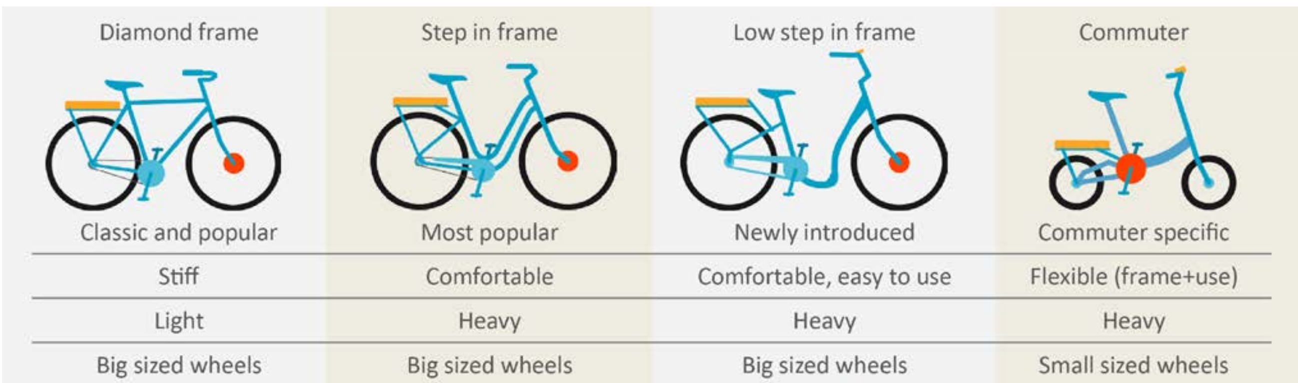


Figure 14. Popular Pedelec frame types

Wheels of big size are also used in frames that give the opportunity to the rider to take a riding position by stepping through, instead of over, the frame. These frames are called 'step in' frames and currently are the most popular for Pedelecs. The elimination of the top horizontal tube makes riding the bicycle easier while at the same time reduces the frame stiffness since the triangular structure is cancelled. This results in a more comfortable handling and riding with the downside of increased frame weight needed to counterbalance the inefficient design.

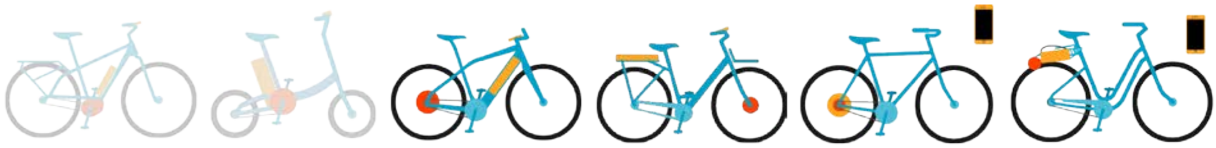
The same principle is used in 'low step in' frames where the rider's entry point is further expanded in the lower part of the frame to promote ease of use. These frames have gained popularity among elderly users and riders with increased frequency of stops. The weight is increased even further both by the need for essential frame stiffness as well by the increased total length of the bicycle. The popularity of these bicycles is increasing mostly because of the pedaling assistance. Having pedaling assistance aids in coping with the added weight as well as reducing the peak force inputs from the rider which in turn require increased frame stiffness.

Finally, another popular Pedelec frame type is the one that incorporates a small sized, usually foldable frame. Pedelecs using these frames have a high focus on flexibility towards urban transportation and product handling. Wheels being used in these cases are of small size and usually frames are lacking stiffness and present increased weight.

3.7 Drive systems

Regarding drive systems that are currently used for providing assistance to Pedelecs these are categorized mostly according to their placement in the bicycle frame. Their placement defines to a certain extent their capabilities and therefore the whole behavior of the Pedelec. There are many, and different, types of drive systems such as bottom bracket drive systems, hub motor systems and add-on motor systems. In relation to the motor placement other components like battery placement, number and type of sensors used, are defined as well. Some drive systems have their own different version types so that Pedelec manufacturers can provide complete solutions for a wide range of different types of Pedelec usage. Controls, feedback, interactions are varied as well among drive systems even the ones from the same manufacturer.

Add-on systems. It is the least popular drive system used currently, mainly due to the systems inefficient principle. The motor, battery and transmission are all included in a volume which can be added onto the bicycle frame and through a friction roller will give motion to the rear wheel (Figure 15). The principle behind this motor application is relatively old since it was first introduced in 1899 as seen in the Pedelec background part of the current report. While then it could be a viable option due to low performance from the competition, today it is almost disappearing from the market since all other systems present extremely increased efficiency. Important points that should be considered are its ease of use and the ability to be mounted on different conventional bicycles.



Brand	BionX	Copenhagen Wheel	Flykly	Rubbee
Torque	25Nm	Not provided	Not provided	Not provided
Assistance levels	4 support modes	Through app	Through app	On/Off function
Battery specs	317Wh	Not provided	160Wh	280Wh
Weight (drive+battery)	9.000Kg Approx	5.900Kg Approx	3.000Kg Approx	10.500Kg Approx
Unique features	Regenerative braking Noise & Vibration free Brushless motor	Regenerative braking	Regenerative braking Motor lock with pin	Only cadence sensor
				

Figure 15. Hub and add-on Pedelec drive systems

Hub motor systems. These drive systems became really popular due to their combined improved efficiency and easy integration to current conventional bicycles. They provide users with an option for performing a Pedelec upgrade to existing bicycles which is reducing purchasing cost significantly. Battery can be placed either within the hub itself or in any other position on the bike. Features that can be provided are GPS functions to track the bike in case it is stolen or while exercising , electronic locking, regenerative function to harness energy from braking or going downhill and many other (Figure 15). Operation of the motor is regulated by a variety of add-on cadence, speed and even torque sensors and in cases from handlebar switches. Controlling the motor's settings is achieved by connecting smart devices like cell phones and tablets.

Bottom bracket motor systems. This is the drive system that most likely will prevail in the future market. It was introduced together with the first electric bicycles and because of its very costly (at the time) integration to the bicycle frame, was neglected. Motors used in these systems present very attractive specifications for both users and manufacturers (Figure 16). They are of high quality and their performance is on top level. The motor usually offers a complete set of features which are condensed in a relatively small package positioned in the bottom bracket area. Sensors used are similar with the ones in hub motor systems and the battery can be positioned into any available area on the Pedelec. Communication with these systems is usually achieved with a variety of optional informational screens and controls positioned on the Pedelec's steering. Pedelec manufacturers created new frame types able to accommodate bottom bracket systems in order to take advantage of their 'all in one part' nature. As mentioned, people are getting familiarized with all the benefits of Pedelecs and are willing to increase their budget towards purchasing one, while production methods are getting better and constantly are adjusted to bigger volumes. As a result, bottom bracket motor systems are gaining ground in the market over their competitors providing to users reliable and efficient pedaling assistance.

Brand	Shimano Steps	Bosch	Impulse 2.0	Yamaha	Conti
Torque	50Nm max	48Nm max	70Nm max	80Nm max	50Nm
Assistance levels	Sensor dependant	4 support modes	3 support modes	4 support modes	4 support modes
Battery specs	418Wh	300/400Wh	396/418/522/612Wh	400/500Wh	405/522Wh
Weight (drive+battery)	5.800Kg Approx	6.200Kg Approx	5.800Kg Approx	7.000Kg Approx	6.600Kg Approx
Unique features	Electronic shifting Start mode Intelligent power assistance Walk assist mode	Automatic gear 3 sensors Gear shift detect Backpedal function	Gear shift sensor Back pedal brake	3 sensors	360 positioning 2 chainrings possible

Figure 16.Bottom bracket Pedelec drive systems

3.8 Battery types-technology

3.8.1 General

The market nowadays can provide many different types of batteries with diverse characteristics. Features and specifications towards cost, watt-hours/kg, safety, recharge cycles and recharge times are rendering optimal battery choices as a troublesome task. With the developing trend of electrical cars, battery technology has become a flaming issue, driving their evolution at much higher speeds comparing to the past. To foresee the battery technology in 5 years is something not easily done.

To be able to compare existing and evolving battery technologies in a well manner specific energy (Wh/kg) is evaluated. Specific energy, is the energy given per unit mass, and it is measured in (Wh) being power(W) over time(h). This is used to compare the batteries since the weight is of the most interest as volume does not differ very much within the interesting batteries.

In the largest e-bike market in the world, China, the VRLA (Valve Regulated Lead Acid) batteries have been most popular due to attractive manufacturing costs and various safety issues. The Lithium-ion is getting more and more popular in China, as well as it is by far the most popular in Europe (Weinerta, J. et.al. (2012)). It's popularity is caused mainly because Lithium-ion technology can provide high specific energy. On the downside it is a technology that has a higher cost and is more sensitive to improper charging. Furthermore, in China the regulation on e-bikes differs from the one in Europe, providing the option of using higher motor power and therefore e-bike products are able to carry increased weight. In the table below (Table 2) some interesting battery types are compared.

				Li-ion			
Cathode material	Lead acid	NiCd	NiMH	Cobalt	Manganese	Phosphate	Li-S
Specific energy (Wh/kg)	30-50	45-80	60-120	150-190	100-153	90-120	165-600
Cycle life (cycles x 100)	2-3	10000	3-5000	5-10	5-10	10-20	15
Charging times (hours)	8-16	ca 1	2-4	2-4	<1	<1	-
Cost	Low	Medium	Medium	High	High	High	Medium

Table 2. Battery comparison (Batteryuniversity.com and www.bike-eu.combreakthrough in battery technology)

The Li-S (Lithium Sulfur) battery seems to be the most interesting, production ready, technology for e-bike implementation. Batteries using this technology present high specific energy values and even greater performance is already been developed for the near future. According to Oxis energy, the developing company behind the Li-S battery, the Li-S batteries have potential to achieve five times the specific energy of today's Li-ion batteries. It is using none of the heavy metals such as cobalt and nickel and instead it is using waste from the oil refinement, sulfur. Li-S battery technology is considered to be less toxic, more environmentally friendly and less expensive for the consumer (Oxis energy, 2015).

3.8.2 Functionality

Battery weight differs significantly for different battery technology types if the same amount of energy is supposed to be stored and delivered (Table 3). Specifically for Pedelecs, just like for conventional bicycles weight is of the biggest concern, then size, in reasonable proportions. Weight relates to the specific energy and can easily be calculated in order to find the batteries required weights. Normal energy consumption on an electrically assisted bicycle is approximately 8 Wh/km (GRIN Technologies, n.d.) meaning that 100 km travelled with an e-bike, would require roughly 800Wh, for comparison purposes.

Example of weight for 100 km biking (800Wh)				Li-ion			
Cathode material	Lead acid	NiCd	NiMH	Cobalt	Manganese	Phosphate	Li-S
Specific energy (Wh/kg)	30-50	45-80	60-120	150-190	100-150	90-120	165-600
Weight (kg)	26-16	18-10	13-6,7	5-4,2	8-5,3	8,9-6,7	4.8-1,3

Table 3. Battery weight examples

The numbers in the table for the Li-S battery is taken from a manufacturer brochure which shall be treated with as such information. The numbers is not from an independent party and the battery is not produced today like the others are and can therefore not be tested on its performance yet.

3.9 Power supply

Built in battery needs energy input from an energy source so it can be recharged. Today the electrically assisted bikes get their energy mainly from the energy grid by connecting the battery to it, through an appropriate adaptor. The most common case is that the battery is taken out of the bike and brought inside the home, workplace or equivalent where it is connected to a charger and charged for the time needed or the time that is available.

Besides the use of the classic electric grid outlet, there are other ways of charging the battery like solar panels and induction chargers. Solar panels do exist today and are successfully been implemented in electrically assisted bicycles (Leaos, 2015). According to the manufacturer the Leaos bike is able to recharge its battery, for travelling 20km per day, on solar power alone. In addition, induction charging is already available for both cars and mobile phones (Figure 17),offering many advantages and possibilities. The battery needs no physical connectors to the environment, enabling a built in solution where the battery can be protected from the environment, and potentially not needed to be taken out of the bicycle at all.

Figure 17. Car and phone induction charging platforms (from left to right)

3.10 Deconstruction of product qualities

In order to provide a good foundation for the steps to follow regarding the existing interaction and context examination, the product is analyzed in regard to its main features and qualities. These product specifics concentrate the essence of the designer's intention towards the reason of the product's existence. The context within the product is to be launched, is defining the needs, the product-user interaction is defining the intended solution and the product qualities will make it all possible. In other words, it can be mentioned as 'why', 'what' and 'how' respectively. Therefore, it is important to highlight all the characteristics of the product both in the details and its general idea since they will lead to further analyzing. Since the deconstruction can be a rather big task the project will focus on features and qualities believed that contribute most in 'how' the intended interaction is to be transferred to the user. Also, to further confine the number of product specifics, one product will be chosen to be analyzed instead of analyzing a series of products that showcase all possible qualities. A product that is accepted in the existing market would be sufficient to provide with the information required. Therefore, the most popular Pedelec type currently in the Swedish market is chosen, that of a commuter Pedelec with a step in frame, having a front hub motor and rear rack battery.

Below follows the deconstruction phase of the existing product (figure 18)

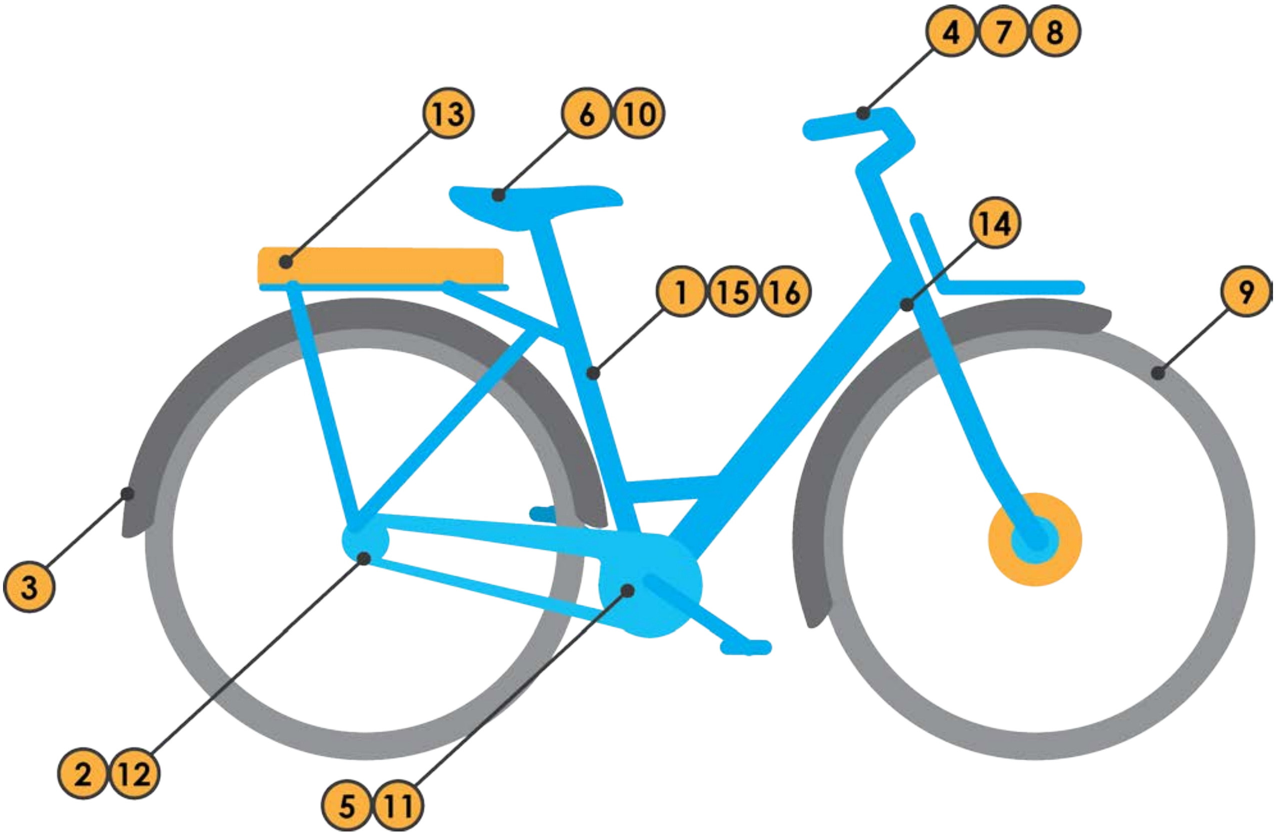


Figure18. Existing productdeconstruction

1. **Step in frame**. The frame is lacking a horizontal top tube which enables the rider to get on and off the bicycle in a easy way.
2. **Internal gears**. Gears are integrated inside the rear wheel hub providing protection from the elements and dirt and therefore maintenance is reduced substantially.
3. **Fenders**. Between rider and both front and rear wheel, covers provide protection to the rider from matter picked up and tossed around by the wheel tires.
4. **Grip shift**. Gears are manipulated with the help of a grip shift mechanism used in the bicycle's handlebar. Grip shifters allow change of gears without losing the grip of the steering since all fingers are around the handlebar while making a shift.
5. **Pedal brake**. A mechanism that allows braking without the use of brake hand levers. By making a reversed leg motion, the brake which is integrated into the rear hub, is activated and is regulated by the strength of the reversed movement.
6. **Wide saddle**. A saddle which offers more contact area for the rider, resulting in a more comfortable ride.
7. **Ergonomic handles**. Specific handlebar grip design that reduces the strain in rider's wrists by providing cushioning and extra support to the hands.
8. **Upright posture**. The bicycle's frame design provides an upright riding position which offers comfort and high eyesight position.
9. **Large wheels**. The bicycle's frame design is completed around large diameter wheels that result in more contact area with the ground, overcoming easier small obstacles and reduced rolling resistance.

10. **Saddle handle**. A handle is integrated in the back side of the saddle to help the user control the bicycle while on foot.
11. **Two legged stand**. A foldable stand in the lower part of the bicycle provides secure placement of the bicycle which is much appreciated due to the high center of gravity.
12. **Three speeds**. The bicycle is provided with three speeds that cover a broad range of gear ratio to cover most riding situations in an urban environment.
13. **Rear rack with battery**. A bicycle frame forms the basis of the Pedelec and the rear rack hosts the volume of the battery. It is a solution that positions the battery in a relatively high placement in an inexpensive manner towards manufacturing since the frame remains unchanged.
14. **Spring for front wheel**. Steering is attached to the frames diagonal tube through a spring that provides stability when the bike is in an upright parking position.
15. **Aluminum tubing for the frame**. A good combination towards manufacturing and material characteristics. Aluminum is a well-known lightweight material with established and well tested manufacturing methods. It presents a good material solution for bicycle frames.
16. **Integrated lock**. A lock attached to the seat stays enables the user to render the bicycle unusable when left unattended.

The above Pedelec qualities are defining areas of interest that can be clearly be noted after categorizing them. Four main groups are formed and reveal the main qualities which make a Pedelec product favorable. These groups are the following

- **Ease of use and comfort**(step in frame, pedal brake, wide saddle, ergonomic handles, upright posture, large wheels)
- **Maintenance** (Internal gears)
- **Functionality** (Fenders, Grip shift, saddle handle, two legged stand, spring for front wheel, integrated lock)
- **Economy** (Three speeds, rear rack with battery, aluminium frame)

The product analyzed is as described a product from the most popular type of Pedelec according to the retailers. There are certainly many other varieties and features in other products to analyze. For the purpose of the project the presented product qualities are derived from the most commonly sold product. Therefore, the most sold features are displayed, providing an understanding of the features consumers are expecting in a Pedelec today.

4 Existing interaction

4.1 Riding postures

Using a Pedelec is not only about the existence of qualities that define it, but also how the user is interacting with them. A main user-product interaction is referred to the user riding position which is defined to a large extend by the Pedelecs frame. As already been mentioned the bicycle as a product has an extended history. Throughout the years a lot of research has been performed regarding efficiency and comfort issues especially since bicycles were used for competitive sport racing usually in long distances that lasted many hours. A lot of the inventions and breakthroughs used in racing were passed on in conventional biking providing improvements in everyday riding. A lot of discussion has been held around bicycle fitting which defines the rider pedaling posture in an attempt to improve efficiency and reduce injury risks. An issue that relates not only to competitive cycling but to everyday commuting as well. Since the physical status of the competitive rider is quite different when compared to an everyday commuter rider, further examination of upright postures used in urban areas was needed.

Since every person presents different body measurements the total amount of ideal or preferred riding positions is vast. There is though, a general categorization that relates to the type of riding each user chooses to perform within urban areas. There are four main categories (Figure 19).

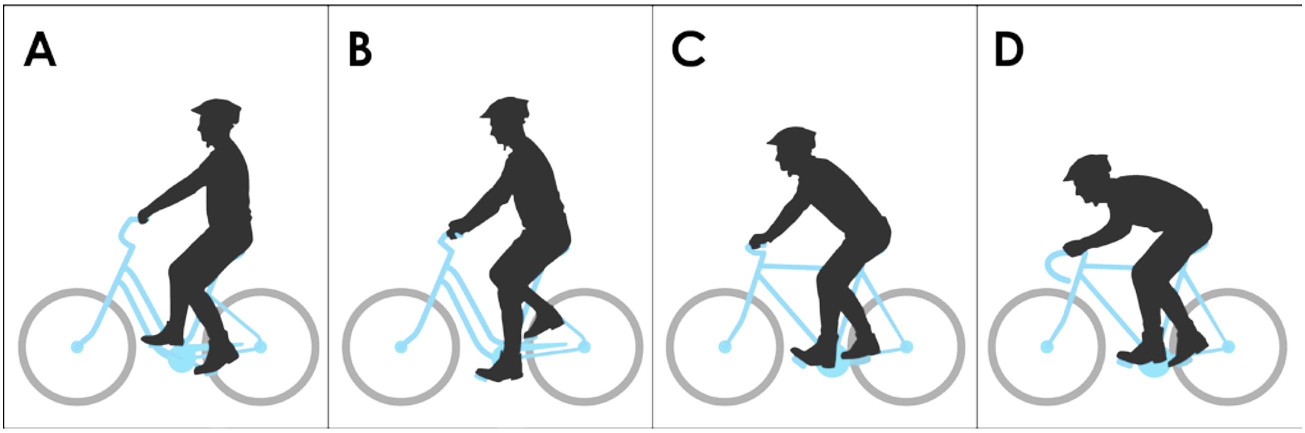


Figure 19. Popular commuting riding postures

A. Dutch. It is similar with the comfort riding posture, except from the fact that the torso is totally upright and can present difficulties in weaker users maintaining it for prolonged time periods. In longer rides fatigue can cause the relaxation of the lower and upper back and cause extensive back curvature which can in turn provoke discomfort and possible injuries. Hands and wrists are supporting only their own weight and due to the upright body posture the weight is unevenly distributed over the wheels. This causes uncertainty in control and tire grip.

B. Comfort. It is probably the oldest riding posture dating back to high wheelers and safety bicycles of the past. The upper torso is leaning slightly forward from the hips which takes the stress off the lower back and offers easier bike control. Adopting a comfort riding posture makes easier to get a peripheral view of the environment and eases the strain on the lower back, hands and wrists. While in a comfort riding position the rider has a high control over the bicycle, at the same time enjoys increased comfort.

C. Hybrid-MTB. Riding in one of these two bike types is currently popular amongst commuters. The MTB booming of later years resulted in a large number of mountain bicycles also been used in cities and eventually formed a riding posture category on their own. The rider's body is leaning forward in order to offer a quick and dynamic riding to the user. Upper torso and arms are more active in propulsion and general body support. In longer rides the strain on these body parts can be overwhelming especially for people that belong to the project’s target group.

D. Road racing. A biking posture that is not common in the city environment but is presented for comparison causes. The position of the upper body is almost in parallel with the ground and promotes the rider having curved back for reducing aerodynamic drag. This position obviously puts a lot of strain in the hands, lower back and neck and is used mostly by well trained people that are able to sustain the posture for extended periods of time without issues. Pedaling efficiency is on a very high level and allows for an easy transition between on and off the saddle pedaling.

4.2 GERT-suit

4.2.1 General information

The GERontological Test suit is product made to simulate many of the physical impairments of getting old, even for younger people (Figure 20). The suit imitates muscular atrophy by using added weights on wrists, ankles as well as to the upper body core, reaching a total weight sum of 18 kilos. Reduced hand gripping ability is simulated with a special type of gloves, while elastic bandages are used to simulate joint stiffness at knees, elbows and neck. The suit also includes narrowing of sight breadth, opacities of the eyes and high frequency hearing loss. It is estimated that the person wearing the suit is experiencing a maximum aging difference in the scale of 30 to 40 additional years. GERT suit has been tested thoroughly by performing various tests by the manufacturer and has proven to be approximating targeted impairments in a very efficient way (Moll, W. 2015) . The following age related impairments can be simulated with the GERT suit in various intensity levels and combinations due to their modular adjustable design:

- Opacity of the eye lens
- Narrowing of the visual field
- High-frequency hearing loss
- Head mobility restrictions
- Joint stiffness
- Loss of strength
- Reduced grip ability
- reduced coordination skills

Figure 20. Age simulation suit GERT, complete without accessories

4.2.2 Experiencing the target group

The GERT suit was used to get a better insight into the target group's bicycling difficulties. The suit presented to project group members a perfect tool to test bicycle commuting from the target group's own perspective. It was used while commuting everyday distances for a two week period (Figure 21). Each commuting trip was recorded with the help of a GPS device and rider physical effort was also recorded by using a heart rate pulse monitor. Speed, time, distance, heart rate and route morphology were available for later reviewing and comparing. Each project member kept a diary with riding experiences and thoughts which was discussed after the testing period was finished in order to minimize influences.
Since the test was conducted in a traffic environment, some safety measures were taken. Narrowing of vision, vision opacities, hearing impairment and reduced head turning capability that the GERT suit could provide were canceled from this test. These factors were later tested in a controlled environment. The 'Muscular atrophy' and 'joint stiffness' GERT suit modules were used to see how they affect everyday bicycle commuting for someone having the impairments common to old age. According to the manufacturer the suit achieves with these modules an excellent approximation of the motor uncertainty that is evident in old age people (Moll, W 2015). Since the suit add 30 to 40 years to the age (Moll, W. 2015), the participants experienced bicycle commuting of people in the age approximately between 60 to 75 years which is roughly the project's potential target group.

The test provided not only valuable experiences for the project but also, actual numerical data. To properly evaluate results from using the GERT suit some reference values were required. Therefore, an additional identical test was performed without the use of the GERontological Test suit. Project members recorded identical data types while commuting in the same routes as the ones in GERT suit testing. It has to be noted that both evaluators use the bicycle as their main mean of transportation on a daily basis so there was not a need defining an adaptation period to the test. One evaluator used a conventional bicycle and the other a Pedelec to extend the search spectrum in both closely related areas.

As the GERT suit offers instant transformation the user is experiencing age related symptoms without any adaptation time, rendering the impressions quite strong. Also, ageing simulation is not a perfect analogy to actual ageing but it gives the project members a chance to understand some of the difficulties of ageing in relation to biking.

Figure 21. Project group members testing the aging simulation suit

4.2.3 Testing day

To extract further information from the use of the GERT suit when biking, an event was created where people tested for the first time the GERT suit on a bicycle. The test was conducted with the help of twelve master students from Chalmers university of Technology who tested the GERT suit while cycling a pre-determined circuit. Students were both males and females in the age range of twenty four to thirty two years of age. They were asked to consider balance, confidence, comfort as well as any other general issue that they would consider interesting. After completing the circuit, test subjects were asked a series of questions regarding their experience. These questions were targeted towards the experience of biking at old age as well as towards verifying observations made during the first performed tests with the GERT suit mentioned in previous chapter.

Once more, it must be noted that the GERT suit offers an instant change in the participant's physical condition and that it is not a perfect analogy to the ageing population. The instant change does offer some interesting directions as the change is so great that all the changes become very obvious.

4.2.4 Findings

After project group members used the GERT suit, gained experiences and observations were discussed and many similarities were found. Due to the simulated muscular atrophy and the joint stiffness, getting on the bike proved to be difficult, both because the rider's leg had to be raised over the bicycle's frame and because of stiff joints and weights made maintaining balance a hard task. Strain on the wrists was high due to having stiff joints and therefore, a difficulty in absorbing vibrations was evident. In addition, muscle atrophy, simulated with wrist weights, was adding considerably to the resulting strain.

Since the suit mimics gripping difficulties and loss of haptic feel in hands and fingers, changing gears became difficult due to feedback loss. On the handles, twist gears were difficult to feel when the mechanism had reached the desired gear and therefore a difficulty knowing if the right gear was selected existed. Displays showing the currently selected gear were helpful but it took focus away from the traffic situation which can be hazardous.

The brake handles were also more difficult to operate due to loss of feel in the grip but the braking itself was not affected much. Since the haptic feeling was affected, there was a small discomfort changing hand position on the handlebar grip due to not being able to sense where the palm was placed on the handlebar, if it was too far out, centered or too far inwards. In general, changing grip or letting go of the handle were accompanied with a small sensation of discomfort in control of the bicycle and the traffic situation. This is an observation which was verified by people participating in the GERT suit testing day since they commented that they felt insecure signaling for turning. Participants needed to be able to maintain control and therefore taking the hand away from the steering was not pleasant.

Another verified observation was that old age simulation affected the pedaling frequency. Because of the stiff joints it was more comfortable and perceived more effective to decrease the frequency of pedaling by using a higher gear. GERT testing day participants added that they maintained a lower pedaling pace due to the provided feel of improved balance. They also remarked their need for a lower saddle position to ensure their control and balance.

Despite the fact that the GERTsuit presented the perfect tool for experiencing old age impairments while biking, some considerations need to be taken into account. The GERTsuit is an approximation tool and it should not be considered to provide absolute accurate simulations. It is a tool that has been developed through scientific observations and research but simulating old age in an absolute manner is impossible due to the lack of solid reference values. Therefore, it is assumed that the suit can only approximate aging related impairments and that further research with the target group is needed in order to acquire an optimal overview of the biking situation.

Findings from the GERT-suit

- Getting on the bike are more difficult
- A loss of balance
- Weights simulating muscular atrophy makes wrists take more strain
- Haptic feedback from gears were reduced making gear shifting harder
- Letting go of the handlebar is accompanied with a feeling of discomfort (signaling for a turn)
- Pedaling frequency is slowed down when joints are stiff
- Lower saddle position in order to put feet on the ground in low speeds

4.3 Deconstruction of product interaction

Pedelecs as products, exactly like conventional bikes, offer the user a broad range of possible ways to interact with. Mostly, the interactions involved are based on physical actions which are clear and relatively straightforward. The user of a Pedelec is interacting physically with the product through specific contact points that enable its operation and manipulation. The basic interaction is defined by the position of the rider over the bicycles frame. It offers a feeling of control over the bicycle elements in every aspect. It is a dominant interaction that is noted especially in frames with a horizontal top tube where the user is challenged to go over the frame in order to use it. In frames with a step in, the interaction is much more settle since the user is invited to go through the frame in order to mount the saddle. This way the connection is more friendly and inviting, characteristics that are favorable for the development of the future product.

Analyzing further the interaction with the product certain areas need to be pinpointed. The saddle is the part that is supposed to carry the rider's weight and offer a comfortable ride. This is achieved with cushioning parts which, depending on the bicycle's use, vary in size and feel. For the needs of a commuter bicycle with an upright riding position cushioning needs are increased since most of the rider's weight is towards the back side of the bicycle, positioned nearly right over the saddle. Saddle shape is defined by ergonomic values that again define different shapes depending on the rider physic and the intended use. Pedals and handles are also points that contribute in defining the main dominant interaction. While positioning of the pedals is mostly based on efficiency related areas, they do not provide any significant further interaction with the rider. On the contrary, steering handles offer much more. Handles accommodate rider's hands which are a person's main input sources for tactile and haptic feedback. Handle texture, shape and material have a significant role to the rider's critical need for control. In addition, the handlebar and the way it is used to balance the bicycle also contributes to the interaction. The frame design, especially around the handlebar and fork area, effects to a large extend the general feel of the bicycle's behavior. Looking into other interactions it is good to mention that gear and brake controls define the rider's interaction with the respective functions contributing to the mentioned main control need.

5 Existing context

5.1 Retailer findings towards existing context

As mentioned in previous chapters, retailers form a respected source of information in relation to Pedelecs. This includes not only product specific characteristics but various findings towards the interaction that users establish with the product itself, buying decision factors and various other information. This information can be used to better define the existing context which the product is meant to operate in.

One of the main issues that retailers noted, was the fact that the most popular Pedelec in the market is also the most difficult to control. Pedelecs that incorporate a front hub motor were mentioned to have instability issues due to uneven weight distribution. Still though, Pedelec models with front hub motor are the bestselling ones. Therefore, it is safe to conclude that riding feel of a Pedelec is not considered to be a basic buying factor. This condition can be easily explained due to most Pedelec buyers, being car users, are lacking bicycling experience to realize differences in bicycling riding quality. People used in commuting with a car consider other factors for their buying decision which are closely related to owning and using a car. Mainly, buying cost, named features and servicing frequency are the points that define their preference towards Pedelec products.

Lack of bicycling experience presents other interesting points as well. People, mostly using a car, are not so familiar with cycling as a physical action and even have increased uncertainty towards the bicycling environment. Being used in car commuting means that a person is used to be positioned inside the vehicle isolated from outer environment stimuli. At the same time car users enjoy a safety feel towards traffic accidents which is provided by the vehicles structure. Pedelecs are lacking constraints and present a totally different approach with open, to environment stimuli, commuting. In addition, some car drivers need to get back into cycling since they have abandoned bicycle usage for a long period of time. These factors cause to the Pedelec rider uncertainty and increased need for control.

Furthermore, retailers noted that Pedelec users expect, and actually do commute, all year long regardless weather conditions. There is a decrease in buying interest during cold and snowy seasons but it is not reflected in authorized maintenance services which are related to actual commuting. This statement is verified by statistical data showing that 18 % of all Swedes use the bike for their commuting during the winter and 11 % actually do it on a daily basis (Cykelsmart.se, 2014).

Moreover, comparing to older times, people interested in buying a Pedelec are far more informed towards technologies used in Pedelecs. This is describing in a good way the change in the context conditions when compared to the recent past. As mentioned, the need for helpful and reliable retailers is evident due to the product's complexity and constant newly introduced features. Informed customers are seeking more detailed information which increases even more the retailer knowledge demands.

Findings from retailers regarding existing context:

- Most Pedelec buyers are car users seeking a new mean of transportation
- They consider factors like service intervals and ask for a service plan, as they would on a car
- Not being used to biking the Pedelec buyer needs more assistance
- Pedelec buyers commute all year round
- As Pedelec gets more popular people are a bit more educated than before

5.2 Target group

Characterizing a person as an 'elder' is not about just reaching a certain age. The target group in this project is identified with some physical and/or mental degradation or impairments, often due to old age. People belonging to the target group, unavoidably, present muscular atrophy and its effects cannot be eliminated. The effect of muscular atrophy is very individual just like the stiffness of joints is, as well. It is very difficult to circle the exact individuals in an age span, but the effects on the human body examined in this project resembles that of ageing and therefore it is natural to limit the target group to the ageing population.

Investigating ageing further, functional impairments tested with subjects from 55 years of age and up showed losses in locomotion capability (35%), bending (28%), hearing (13%), grasping (13%). Among the individuals of 70 to 74 years old, about half felt like they had difficulties with performing everyday tasks with joint arthritis being the most frequent limiter to activities (Kroemer, K. 2006).

More specific, ageing leads joint components to deteriorate, making them less elastic and stiffer. This leads to diminishes in joint mobility and in many cases, to arthritis which is a painful inflammation. As mentioned before muscular atrophy, is making muscles tougher and with fewer nervous connections, resulting in loss of strength as well as slower motor coordination. The ability to sense tactile, visual and acoustic clues decreases due to loss of arterial and venous flow, leading to a decrease of stimulation and conduction activities in the nervous system. Both sensation and perception diminish and information processing in particular, is slowed (Kroemer, K. 2006). Simultaneous changes in the cerebellum and motor cortex affects the regulation of movements, posture and balance. (Kroemer, K. 2006). Mental performance is not as affected by age, in less complex tasks, but when complexity rises, young adults and middle age-adults perform better than old people. Learning and remembering is not as rapid as it used to be but there is no problem with learning still (Kroemer, K. 2006). Training or maintaining physical or mental activities can prevent reductions in ability significantly. Hearing is greatly affected by ageing declines, first the high frequencies 20 and 10 kHz and even lower, known as presbycusis or age-related hearing loss (Kroemer, K. 2006).

The right measures such as tools, controls, procedures and the use of powered assisted devices can significantly mitigate the age-related issues (Kroemer, K. 2006).

Taking the compression of morbidity into account (analyzed in chapter 6.2.2), the age of the group presenting such impairments will be pushed forward. Being healthier for a longer time as the life expectancy increases means that the age group that is targeted today will present different attributes in the future. Living an active life, some of the impairments due to old age will be pushed forward in age, meaning that if the goal of this project is achieved by making people more active, the age of the target group will be pushed higher as well.

The age of target group is therefore difficult to precisely define and is therefore somewhat simplified. The target for this project is to make it possible and easier for people with a lighter type of mental or physical impairment to transport themselves as well as activating themselves in everyday life.

With all of the above in mind the project has chosen to focus on the age span of 65 to 80 year old people. The target group has been chosen both for statistical data but also for the possibility to analyze their attitudes and problems towards bicycle usage.

5.3 Interviews with target group

After an extensive information search including own experiences with the GERT suit enough information about the target group was collected and understood in order to put together a interview frame. For this project the interesting information lies in the qualitative information elicited through interviews with open questions based on the insights from testing the GERT suit as well as from the information search. To test that the questions elicited the desired information four pilot interviews were conducted to ensure that the questions posed were initiating discussions in the desired direction. After the pilots, the interviews included questions about daily habits which lead to probing questions about the transports made. The interviews also included more specific questions about different bicycle types and riding postures. The goal with the interviews was to elicit qualitative data about the habits and attitude of the target group towards transportation in general and bicycling in specific. The participants were eight in total both men and women, with age ranging from 62 to 74 years old. The session took place at Allegården pensioners cafe (Figure 22).

Figure 22. Discussing details before target group interviews

5.4 Persona

The results of the interviews were best concluded in three personas. The personas represent three different cases to cover the different users and their corresponding needs. The target group is not uniform and there is a large degree of variety for this project. The most common problems with age are being handled, as well as the individual differences found in the qualitative interviews. The personas also reflect the insights from the tests using the GERT suit while biking. The goal of the personas is to describe the issues and attitudes of the intended target group.

Valter represents the part of the target group that neither like nor dislike technological products. He does have some experience of technology but don't like when things need much learning. He has some age related impairments like arthritis, slight loss of hearing and vision and finds balancing more difficult than before. He lives on a hill, meaning that he will walk uphill pushing the bike, because the load on the knees when biking uphill is too high. Also, difficulty in balancing makes him uncomfortable going fast especially while going downhill. In that case he finds difficulties in using the brakes combining in a well manner both front and rear brake effectively. In general he tries to keep active but his joints hold him back. Therefore, he wants to incorporate some exercise into his everyday life to maintain his physical abilities in a adequate life.

He is still working even if he is retired; now he only works when he wants to. When he doesn't work he likes to build things in his small hobby workshop, that is when he is not exploring the world on his travels, off course. Valter likes planning and order and seldom goes on unplanned adventures (Figure 23).

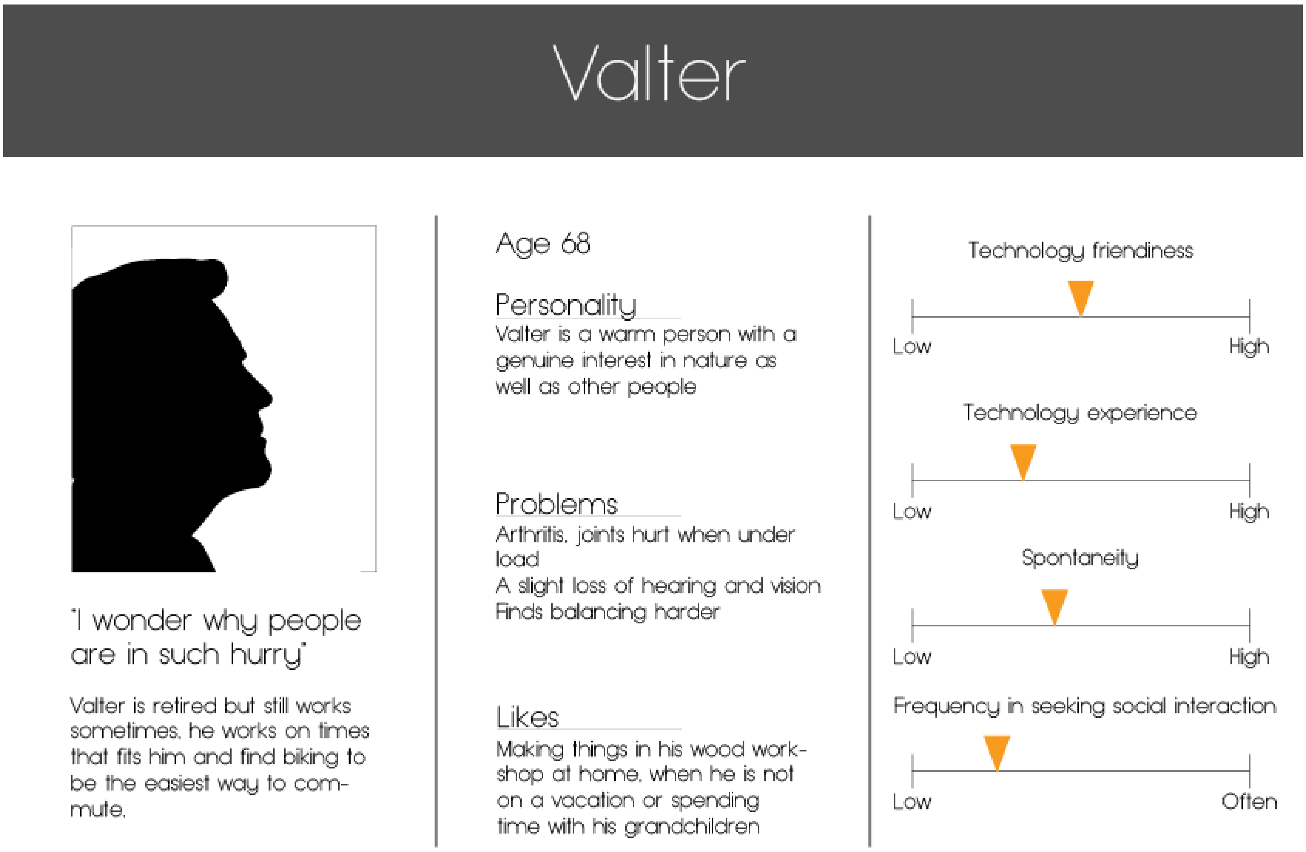


Figure 23. 'Valter' persona informational card

Signe is the most social among the personas with a frequent need for personal contact with other people. Even though, she really enjoys the breakfast she eats on her own everyday reading her newspaper. She loves trying new things, that is why she recently followed a ukulele course at the pensioner's café where she also meets her friends. She does not like taking the bus or tram because then she is restricted to specific departure times and destinations; it's not spontaneous enough, therefore she prefers using her bicycle.

Her children left home long ago and she has recently become a great grandmother. She loves spending time with the fourth generation; the problem is that they live across town and some more so it's a long 22 km bike ride to their home. Signe is not fond of the trip since it means going through the central parts of town. There, it is difficult to keep track of other cyclists riding fast and people walking reckless with their headphones on not paying attention to traffic(Figure 24).

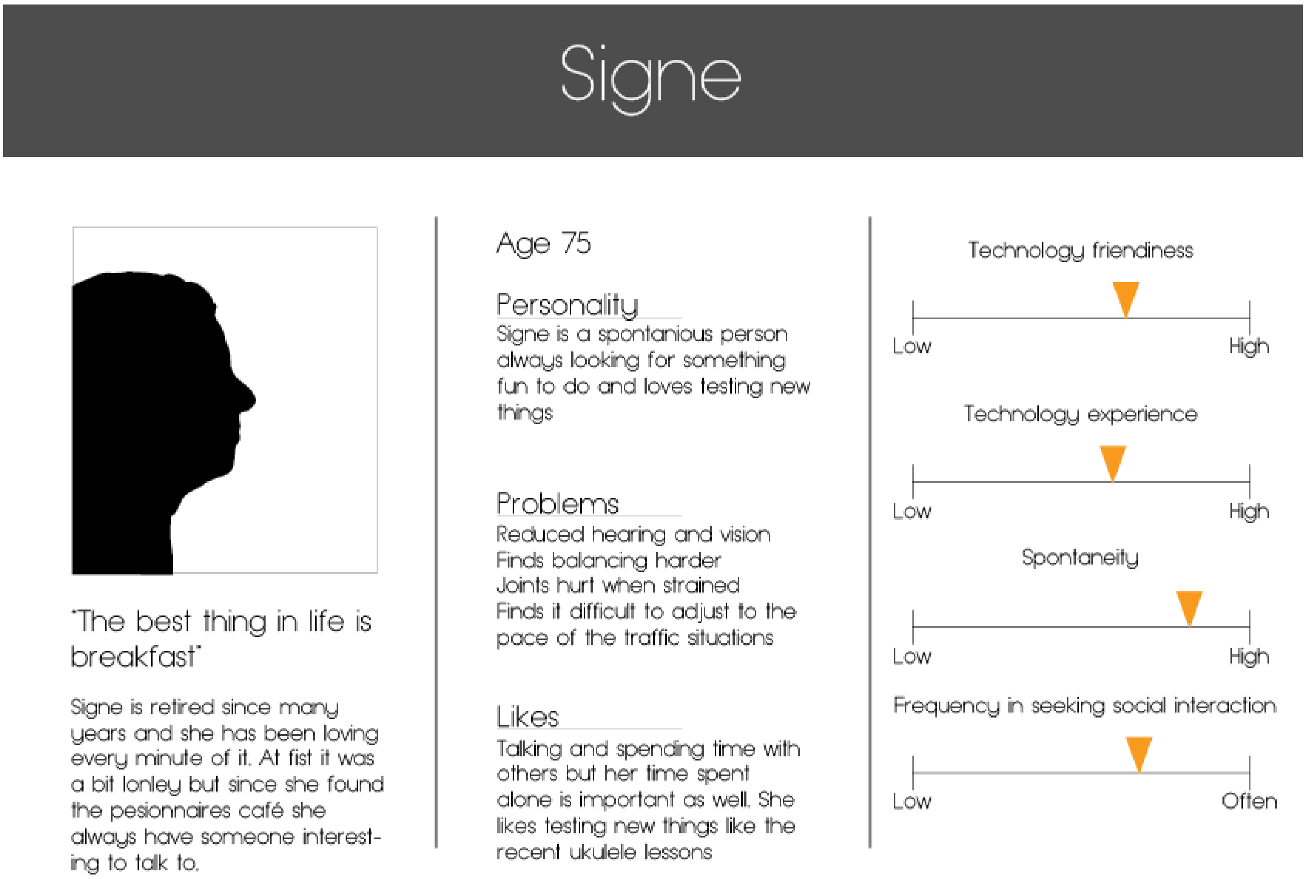


Figure 24. 'Signe' persona informational card

Mats lives a busy life on the verge of retirement and has never being working so intense before. He is a man who sets high goals and then work till they are achived. The only thing he has not been able to achieve is his personal goal of getting fit. A recent visit ot the doctor showed that he lives a too sedentary life and needs more exercise. An old knee injury is keeping him from exercising like he used to, he cannot go running and just has no time for going to the gym. The high workload makes Mats a man with routines and there is no time for spur of the moment stuff.

He lives across town from where he works and that is the reason he takes the car to work. He ends up every day with the same problem, circulating and trying to find a parking spot. The same thing happens when finds the time to watch a game of hockey, hes a big fan of Frölunda Indians and trys to go to their home games.

In his work Mats uses many technological solutions for effective work. He has a lot of experience and thinks that technology combinded with well thought planning can either achieve or improve anything (Figure 25).

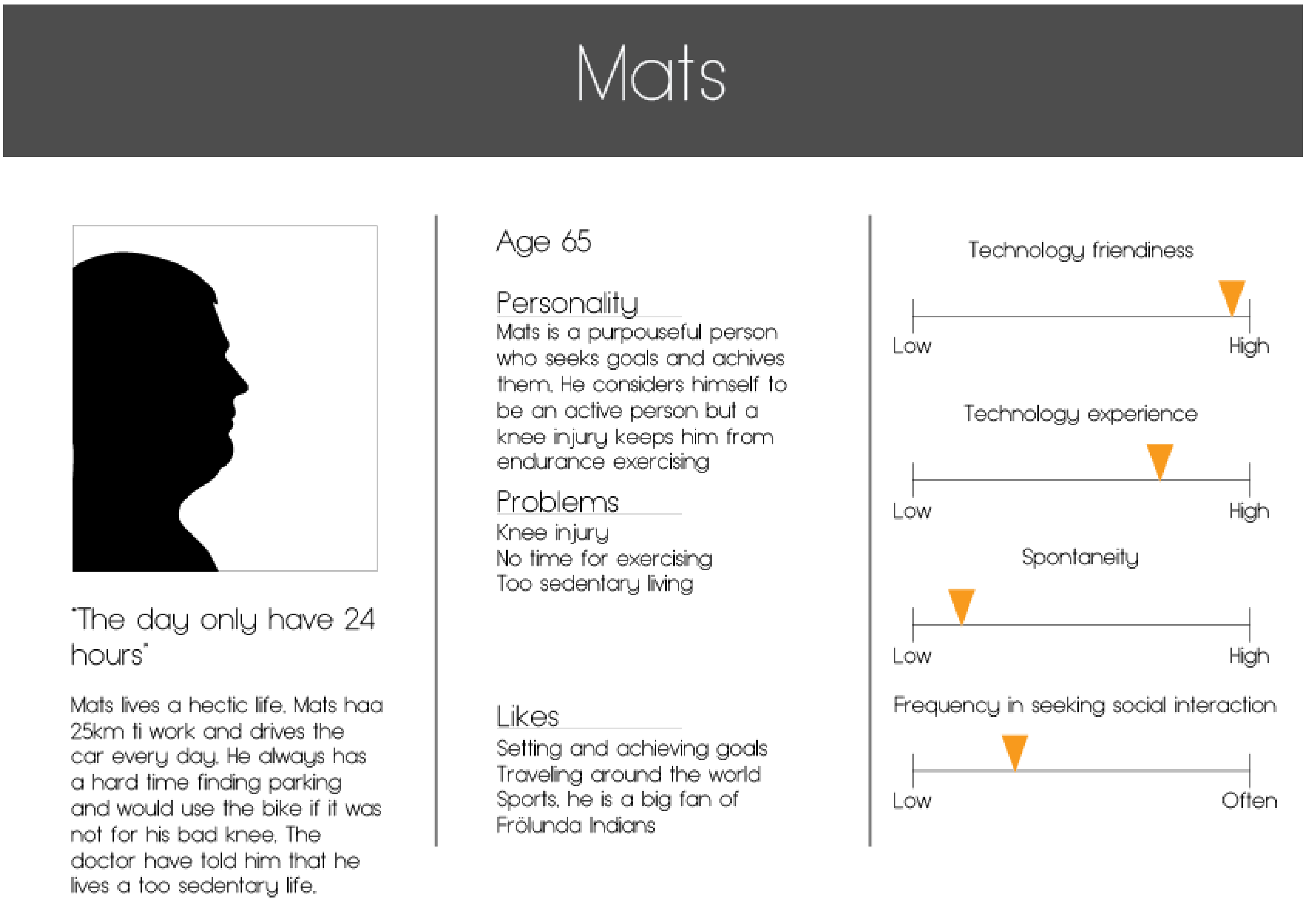


Figure 25.'Mats' persona informational card

The different personas method is a structured way of concluding personalities, impairments and attitudes.It will be used in the ideation, defining the product qualities, in the form generative stage, when designing the product expression for evaluation and in the iteration and second design phase.

6 Future context

6.1 Domain

Defining the future context can be a troublesome procedure. Some filtering, on observations and considerations already made for the project, has to be implemented in order to narrow their amount and be able to define in a good manner the future situation. This filtering is achieved by using a specific domain, in which defined factors are relevant. The domain describes the area where the product will aim to make a contribution (Hekkert, P. van Dijk,M. 2011). Considering the goal and purpose of the project a domain was chosen, described by the title 'Future individual commuting for the ageing demographic'. It will aid the project to consider factors within personal everyday transportation for people which present age related difficulties. In addition, a time horizon of 5 years was specified so further filtering could be achieved.

6.2 Context factors and structure

A crucial part for defining the future context, within the future product is to be operated in, is to pinpoint and structure various context factors. In detail, context factors are elements like observations, thoughts, theories, laws and considerations that form the basic building blocks of the future context. They are 'value free descriptions of world phenomena as they appear' (Hekkert, P. van Dijk,M. 2011). The factors used are extracted from personal experiences as well as from knowledge acquired from the research phase. Factors are characterized according to their nature into Developments, Trends, States and Principles (Appendix A3).

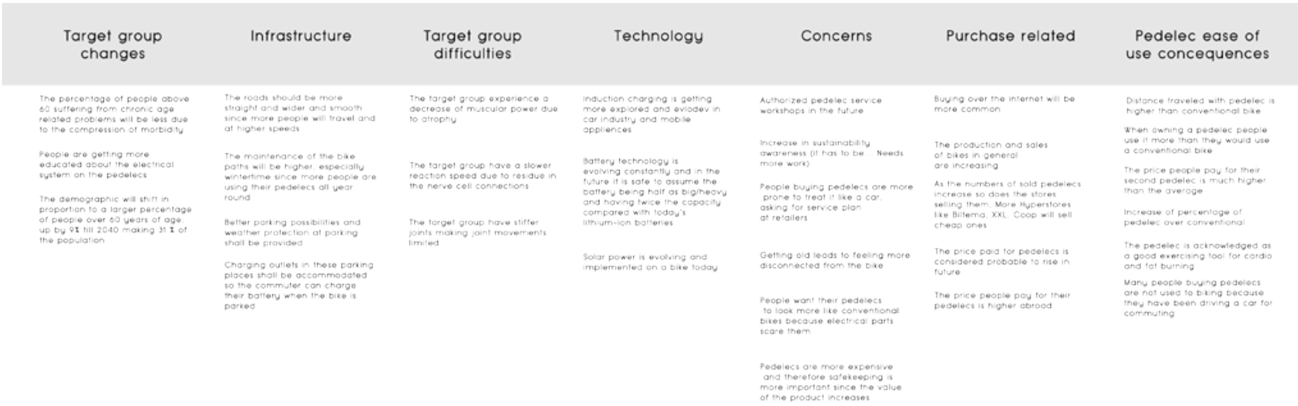


Figure 26. Grouping future context factors

To further organize the findings, factors were grouped according to common qualities and emerging qualities. Emerging qualities were formed by combining a number of factors that presented different qualities and by doing so newly established qualities were shaped. The categorization is clear in the image above (Figure 26).

All of the above information is used to construct the future context which, together with some additional information, will provide the basis for designing the future user-product interaction.

The context is a combination of findings constructing the surroundings and environment in which the product will function and exist. Defining the context involves a great deal of uncertainty since the future is not set. The context is based on findings and interpretations of findings. Here the designer's role of finding the relevant factors comes into play and as this is highly subjective it is difficult to analyze the absolute validity of the factors.

6.2.1 Demographics

In the future context in which this thesis has its focus, demographic changes are of interest. The population on earth is increasing but also changing proportions. As the number of newly born decrease, the demographic is experiencing a change in proportions with the older generation been increasing. This has been a fact for the more developed regions of the world for some time and the most rapid change takes place in the less developed regions of the world. Nevertheless, a change in the more developed regions is still evident even though is not so strong as past times.

The demographics of developed regions of the world, to which Sweden belongs, have experienced an increase of persons 60 years and older for half a century, and the trend still continues. For the coming half century a change in proportions like the one preceding it will be experienced. Considering the growth of the entire world population, the number of persons 60 years and older is still increasing substantially. It is the group which is increasing the most, and in the long run, it will be the only group increasing till 2050, according to projections by the UN (Figure 27). In developed regions of the world the expected amount of years to live after the 60th birthday will increase from 23 to 26 years till 2050. In percentage, the proportion of people 60 years or above has shifted from 12 percent in 1950 to 23 percent in 2013 and is projected to 32 percent of total population in developed regions of the world in 2050 *(UN, 2013. World Population Ageing)*.

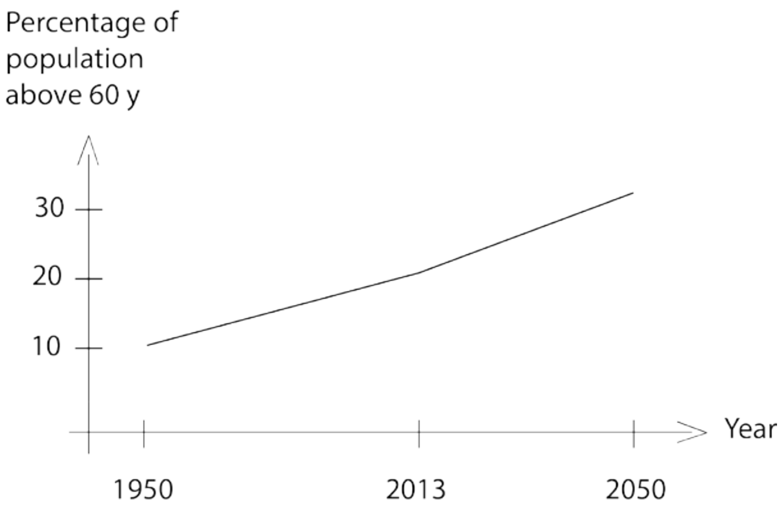


Figure 27. Projection on the percentage of people over 60 years of age

The major reason for the change in proportions is that the fertility rate declines rapidly. From 5.0 children per woman in 1950, fertility rate globally dropped to 2.5 children in 2010 and projected to fall to 2.2 children per woman in 2050 or even as low as 1.8 children per woman. In the more developed regions the fertility rate has declined from 2.8 children in 1950 to 1.7 in 2010 and is projected to rise to 1.9 till 2050. This is below the replacement level of 2.1 children per woman *(UN, 2013. World Population Ageing)*, with replacement level being the amount of children needed to be born in order to sustain population levels.

6.2.2 Infrastructure

A crucial group of context factors is referred to the physical environment in which the product will be operated, the infrastructure. It defines to a certain extend critical points that will affect the intended user-product interaction. To better shape the infrastructure in a future horizon of 5 years a series of contributing factors were considered. Statistics showed that there is a distinct continuous development of the Pedelec and bicycle market which will force many of the relating infrastructure future changes. These changes will be varied depending on current situation, development rates and many other conditions but some general main development directions can be mentioned.

As the number of bicycles used in urban areas continues to grow, bicycling lanes will be established and extended. New materials and production methods for bike lanes could eliminate the need for suspension systems, big sized wheels and thick tires preserving at the same time all the current riding qualities. Possible improvements in the equipment used for traffic signaling could aid the target group enjoy the product in a more relaxed way while feeling safe. Also, charging points will be more popular both in personal and public spaces using technologies that have been recently introduced in the automotive industry. Induction charging was mentioned that is currently used to eliminate the need of a physical connection of a car's or a mobile's phone battery with the power outlet. Therefore, charging batteries can and most probable will be wireless, simply by just placing the product above a specific energy emitting surface. In the same manner Pedelecs could be easily fill their energy reserves while parked or stored.

Defining the future infrastructure is a complicated task since it combines a series of unpredictable factors. Despite the fact, the above future characteristics can be noted with relative certainty.

6.2.3 Battery technology

As described in the chapter on battery technology, it is difficult to foresee the development in the battery industry. The battery chosen is based on existing knowledge of batteries as well as a reasonable assumption for the future. The technology which shows the most promising future application is Lithium Sulfur battery technology. This is because of Lithium Sulfur batteries present a higher theoretical specific energy specification. Also, it is a technology on its way into the market which is in line with the battery chosen for the future product.

The battery will have a specific energy of 600Wh/kg, and is deemed probable to enter the market in 2016 according to the manufacturer, Oxis Energy. To get enough power from the battery the voltage is set to the most usual today, 36V. As the bicycle includes more functions than today's Pedelecs, the stronger 14Ah battery is chosen. Today the batteries produce somewhere around 70km to 135 km per charge according to manufacturers (Figure 8).20 km per trip (10 each way), made for five days in a week and charging the battery once a week leads to a distance of 100km per week.
The possibility for charging the battery does affect the needed battery capacity. Having a power supply to charge more often would reduce the need of big batteries. For example having solar panels like the ones used on the Leaos bicycle (LEAOS, 2015), can result in Pedelec charging during daylight and increase significantly commuting range solely using solar power.

The possibility of induction charging also presents an interesting possibility. The technology, as mention previously, is already used in electrical cars (Plugless power, n.d.). By positioning the vehicle over an induction plate, battery is charged through induction and therefore is not needed to be plugged in with a cable power adaptor. Having this in the parking place of the bicycle would mean that the battery is charged whenever it is parked, minimizing physical effort and relating procedures. Also, using induction charging, charges will be more frequent reducing the need for a battery with high capacity. The possibility of longer trips is taken into account though. Therefore the range of 100km per charge is chosen in order for the user to feel confident about reaching the goal of their trip. With an intended range of 100km per charge the weight of the battery can be calculated. For normal use the energy consumption is approximately 8 Wh/km (GRIN Technologies, n.d.). This means that the battery needs to produce 800 Wh of energy in one charge. Using the high performance Li-S battery, with the specific energy of 600Wh/kg, gives a battery weight of 1,33kg.

As the information found on this new technology only presents energy density per weight the volume of the battery is difficult to calculate. No remarks about the energy density in relation to volume are mentioned, therefore it is assumed that it has the same energy/unit volume as today's batteries. The size of this battery can therefore be compared with the existing lithium-ion cells. The exact dimensions of the cells can differ and the future battery dimensions will be approximated. As an example an existing battery will be measured, a battery made for a Pedelec(Figure28).The volume which contains the power cells in this battery is 160x280x45mm in size and it weighs 4,25 kg. This gives a density of approximately 2,1 kg/l. Considering the calculated density the future battery could reach a volume of 1,33/2,1=0,63 liter which is a considerable reduction of volume and weight. This reduction can introduce design changes to the problem of battery placement in pedelec cycles as it will be seen next.

The future for batteries is, as mentioned, difficult to foresee. Since the battery technology chosen is so similar to today's batteries a difference than what is expected in this project would not have a big impact on the concept as such. The difference in size is relatively big comparing the batteries, but in relation to the whole bike the impact is not as big.

Figure 28. Volume reference battery model

6.2.4 SWOT

The context in which the product shall exist offers a different set of possibilities and limitations than today, although it will resemble today's scenario. SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) is used to identify the different possibilities and limitations of the product within the specified context. It is carried out as an ideation session to spot all interesting factors, using both knowledge of the future as well as possible scenarios (Appendix A4). To be able to use SWOT analysis in an efficient way factors which formed each field were closely examined and summarized (Figure 29).

Figure 29. SWOT analysis factors

The main strength of a Pedelec in the future will be that it will still offer attributes that are favorable to the project's target group. While Pedelecs will become more efficient and able to provide even better characteristics, the general status of older people will be characterized by roughly the same physical difficulties known to older people today. On the other hand, the main product weakness will be the higher complexity that it presents in comparison to a conventional bicycle both in form and technology used. As for the opportunities that Pedelecs can present, these are mostly related to the fact that they carry a reliable power source which can drive countless new features for the user. These features are referred both to new innovative technology as well as to already existing technology from other areas which are now able to be introduced into the bicycling context. By having the opportunity of implementing more features to a Pedelec it further increases its status in the transportation mean map. But threats need to be considered as well. The main threat is related with future infrastructure changes and to which extent these changes will include the use of bicycles and Pedelecs.

The SWOT analysis does not in itself bring new things in regards of information but it helps organizing and in some case pinpoint the most interesting ones and put them in the spotlight. It also helps in focusing on the different angles of factors, if it is an opportunity or a threat, and thereby eliciting and categorizing factors. No revolutionary findings came out of the SWOT and it could with benefit been made earlier in the process to expand the search of interesting context factors.

6.3 Production and cost

Despite the fact that the product is targeted for the near future making it difficult to predict production methods used and their relating costs, some estimations have to be realized. Considering the pace innovative technologies are implemented into manufacturing procedures it can be concluded that in five years time the manufacturing scene will not be extensively different if compared to current capabilities and costs. Opinions from experts in the manufacturing area verified the above statement. Manufacturing technologies related specifically to bicycle production are optimized throughout the years, since it is a product massively produced for a long time period and therefore, manufacturing costs are mostly related with labor and material cost. Even technologies and materials introduced relatively recently into the bicycling field, like composite materials, did not present differentiation into their implementation in production or cost reduction curve. Despite the small reduction in material cost and the higher degree of automation, the consecutive steps needed for reaching a final result, keep tooling and labor costs on a high level. Therefore, for the needs of the project manufacturing capabilities and relating costs will be regarded similar to current times.

Trends analyzed in previous chapters showed that there is a clear increase in the available budget for Pedelec acquisition. Also, Pedelecs are increased in production and their manufacturing cost will decrease, if supposing, features and production methods are kept unchanged. Considering the above statements it is evident that there will be room for taking advantage an excess value in the market. This can be translated as increased feature implementation, use of more complicated production methods or a combination of both. In particular the manufacturing method used today is the tubular hydroforming which enables the realization of complex frame and part shapes. This method does need a high production amount to be economical since it has a high initial tooling cost.

6.4 Statement

To translate all the results from the research phase a statement was formulated. The statement, according to the ViP method, describes *what* the product will offer the intended users. The statement is a collection of short sentences meant to define what to offer but in no way suggesting how it will be reached. This is meant to keep all the possible solutions in mind and is the first step in establishing a vision of a product design. Therefore *what* the project's product is aiming to offer to its targeted users can be described as (Figure 30):

“**Enable** the user to feel fully **capable** and active”

“Bring back the **interaction** with the **environment**”

“**Enhance** the interaction with the traffic situation”

Figure 30. Statement definition

The product’s main focus will be to redefine how people feel towards their physical state. It will make them feel able to perform physical activities by compensating with what has been lost due to aging or other factors. The fact that the product is meant to be used outdoors will attract people to reconnect with their physical and social environment.

The statement is also important since it communicates, in a very simple and straightforward way, the very essence of the product aim. It defines in an open and relatable way what the target group needs and what the product is to offer. It keeps the focus clear for the project participants and keeps them on track.

7 Future interactions

The statement defines *what* the product shall offer, and the established user-product relationship defines *how* this will lead to the specific goal, again without suggesting specific solutions.

To ‘enhance the interaction with the traffic environment’ is defined as enhancing the situational awareness with multi modal communication between the environment and the rider. The situational awareness is dependent on the input acknowledged as feedback from the environment. If the senses are impaired due to age-related changes, the feedback such as auditory and visual might not be enough to create sufficient situation awareness. This leads to an uncertainty and reluctance to use the bicycle, as expressed in the interviews with the target group. It was expressed in quotes like “other cyclists are biking too fast!”, off course some cyclists bike too fast but also the target group have an inability to foresee other cyclist passing at high speed.

The situational awareness is related to how the input correlates with the interpretations made in the situation. If the input is insufficient the situational awareness will suffer. To increase the situational awareness not just more information is needed, but the right information as well. When biking many senses are in use, with visual and auditory senses being the most prominent. Visual sense is looking forward and to the sides scanning the situation while the auditory adds to the visual by sounds from all around in the situation. If hearing is impaired the area that is “scanned” shrinks to what is in front of the cyclist. The senses of the cyclist can be increased or amplified, but the information must be of the right kind and in the right time and place in order to aid the situational awareness in the best way.

In an cycling situation many things happen simultaneously and senses shall be used to their greatest extent. The Wickens model of multimodality, or the multiple-resource model, state that two different perceptual modalities are best to be combined when communicated simultaneously (Wickens, 1980). A modality is the channel through which the sense is communicated. The visual sense is mainly used in the situation of cycling so that would be in conflict if further used. Other senses are the auditory, haptic, smell and taste. Smell and taste seems not useful in a cycling situation but auditory and haptic senses have a potential to be used to increase situational awareness.

8 Future product

8.1 Constructing a Theme

It was found in the focus group that since the product is supposed to help the ageing population to keep active it could be seen as an aid for elderly. If the product though, is designed as an aid for elderly it compromises the feeling of being capable since the person is using an aid as help. Therefore, it is very important to design the product in a way that does not communicate aid for elderly or impaired.

As expressed in interviews with the target group and in the interviews with retailers, Pedelecs are seen as complex products. It is visual obvious when a bicycle is electrically assisted and this fact is certainly negative since the, much appreciated, simplicity of the bicycle is compromised. According to the interviews with retailers, most Pedelec buyers, especially elderly, buy the Pedelec due to the sale of their “extra” or “second” car. The car is seen as expensive, complicated and an ineffective mean of transportation in an urban environment. Therefore, they look for a substitute, and often expect this to be treated much as a car, and thereby treating it like a complex vehicle.

To design a product after a theme, one main word is chosen as a guide to what the product shall express. in this case it is important that the users want to use the product and use it extensively and therefore, it shall be *inviting*. Inviting can mean many things depending on the interpretation. This is reason that, three so called help adjectives were chosen to further define the expression inviting. As help adjectives for the intended expression *exciting, simple* and *capable* are deemed as appropriate*.* The theme is to steer the design but also help generate design features and therefore, the three help adjectives are given further explanations in more explanatory words and sentences. In this part of the theme the words shall be directly related to steering and generating form and so, they are called form drivers. Form drivers can be seen in the theme below (Figure 31).

Figure 31. Theme definition

The intension of the theme is, much like the statement, to keep the project members on track in the design process. When the theme is set it is the help adjectives which gives the most help in the design process.

8.2 Ideation

The project's ideation phase was divided into two different areas of interest. The first one was focused on features towards situation awareness and ease of use, while the other focused on the product's form and how chosen features could be integrated into the product without getting away from the targeted visual expression.

From the performed research, a need to improve the user's situation awareness while riding and the general ease of use of the bicycle was noted. It was found that stiff joints is a problem for many users when operating and entering the bike as well as in low speeds before stopping. While riding, the feeling of being disconnected from the bike was expressed and therefore, constant and good grip of the handlebar was needed due to insecurity in balance. Other things to consider were the increasing value of the Pedelec and therefore the increased risk of theft, performing tasks that require a generous amount of carrying capability and many other issues mentioned in earlier chapters.

The increased number of noted issues, in need for a solution, lead to the delimitation of ideating around the ease of use and the situational awareness as these were seen as the main obstacle for people using the bike. The mission to make the users feel capable and active was considered to have higher importance if compared with, for example safekeeping or various other add-ons, like carrying baskets.

8.3 Focus group

To initiate the ideation phase for the product's qualities a focus group session was realized so an extensive idea tank would be established (Figure 32). The participants were given general information related to the project's aim and were presented with three different focus areas. An initial discussion was held in relation to general features that could be implemented in a bicycle targeted towards old aged users. The focus was later on directed to features that could improve the user's situation awareness. Before ending the session, the group discussed features that are related with the opportunity to implement technologies to a Pedelec which require energy from a power source. The outcome of the focus group verified some of the initial concepts from the ideation phase and pinpointed many more possibilities. The most important findings from the focus group are presented in Appendix (Appendix A5).

Figure 32 Focus group

The focus group was conducted with colleagues at industrial design engineering at Chalmers. This could have benefitted from having people from the target group attending. The ideas and discussion during the focus group session gave results with which the project could be taken forward. If these ideas could be found with another ideation method is uncertain but likely. The focus group had the great benefit of associative discussions and being highly time effective.

8.4 Product qualities, features

Results from the ideation sessions, performed from the project's group members, were combined with inputs from the focus group phase in order to constitute an extensive list of Pedelec product features. These features were evaluated against factors that were either desired for the project's Pedelec or were affecting its desirable product qualities. The performed evaluation distinguished many needed features for the future Pedelec as well as some required specifics. The requirement was referred to the fact that some features despite their low score in the evaluation are fundamental for the implementation of other very attracting features. The evaluating table can be found in Appendix A6.Chosen qualities for the future Pedelec are presented next in the form of a table (Table 3).

	Feature	Detailing
Ease of use	Low height motor positioning	The electric motor is placed at the bottom bracket area, concentric with the crankshaft allowing the use of automated gears. Center of gravity is kept in a low height
	Automated gears within the motor	By implementing a motor that can regulate the transmitted power ratio to the rear wheel, the need for extra gearing mechanisms is eliminated. Gear shifters, derailleur and internal gear hubs, cables and specific sized drive cogs can be skipped
	Low step in frame	Frame design that offers a more friendly interaction between the product and the user
	26” diameter wheels	Using 26” wheels allows more freedom to the Pedelecs frame design when compared with commonly used 28” commuter wheels. At the same time, it aids towards keeping low center of gravity while having most structural elements positioned lower
	Increased bottom bracket drop	The user adopts a riding position which is closer to the ground being able to support the rider-Pedelec system in a good manner using the legs. Also, lowers the center of gravity since every piece of the frame is directed towards the specific area.
	Reduced crank arm length	Lowering the bottom bracket is limited by crank length. Using short cranks allows the bottom bracket to be lowered extensively while at the same time a reduce in the user’s leg joint movement is achieved.
	Fork trail and offset values used for commuting	Chosen values have been tested and tweaked throughout the years for commuting purposes and are implemented into the new design.
	Back pedal electronic braking	Use of electronically regulated brakes eliminates the main disadvantage of the conventional back pedal brake. By introducing electronic back pedal brake the braking force is created by a motor which is regulated from a centered control. Electronic backpedaling is not physically resulting into braking but it controls the command to the centered control to brake.
	Regenerative energy function	Users are able to gain small energy inputs while going on a downhill or while using the brake. During these conditions the motor will be engaged, returning energy back into the battery. Accelerometers control differences between coasting and going downhill.
	Inductive charging	Wireless battery charging achieved through an energy transmitting surface situated on

		the bottom area of the parking space. An inductive coil will receive the energy and transfer it to the battery
	Belt drive	Maintenance is kept in low frequency and silent operation is ensured. Need for having a chain is eliminated since peak transmission powers are eliminated because of the assisting motor.
	Automatically adjusted saddle height regulated by speed	Lowering the saddle when the speed is reduced and reaches close to full stop. When speed is increased the saddle will slowly return to its proper height providing a proper riding posture. Regulation of saddle height will be achieved by a centered hydraulic pump.
Situation awareness	Option adjusting pedaling assistance in relation to physical condition	Rider will be bonded electronically with the bicycle establishing a new type of user-product relation. This type of connectivity will be offering optimal exercising conditions since there will be no effort peaks into the workout. Physical condition can be monitored through electronic sensors towards heart rate pulse, breathing frequency and other similar.
	Combined wheel braking with Antilock Braking System (ABS)	By controlling braking electronically, implementing existing ABS technology will be possible. Brake calipers will be driven from the centralized control.
	Integrated front and rear lights	Strong and reliable front and rear lights are integrated into the Pedelecs frame design eliminating theft issues
	Combined auditory and visual signaling	Bidirectional communication with the environment is improved by using multimodal triggering. Auditory bell sounds are combined with strong instant lighting from the Pedelecs head light.
	Proximity tactile signaling	Integrated vibrating devices into either side of the handlebar as well as to the saddle will notify the user of vehicles approaching from the back in order to prevent accidents.
	Directional speaker use	Speakers integrated into either side of the handlebar will be used for entertainment, navigation and communication, eliminating earphone usage.
	Turn indicators are operated with concave capacitive switches integrated in the steering	Thumb operated capacitive switches situated next to the handlebar grip.
	Brake lights operated automatically with back pedal brake use	Eliminates the need of user input for signaling stopping and slowing down

Table 3.Product quality and feature list

8.5 Evaluation and iteration

Using the gathered information from the research phase as well as from the focus group, four concepts were generated (Figure 33). The concepts presented different solutions towards their aesthetic form, just to set a starting point in the project's initial evaluation phase. The basis for the concept generation was the, previously formed, product statement and theme. All of the concepts implement an open character that was expressed mainly through the Pedelecs low step in frame. Frame design restrictions and initial ideas formed the constraints which defined the canvas on which a defined form was investigated. In addition, concepts were lacking details like cables, fenders and carrying features that would distract attention from the main frame. Form complexity, robustness and dynamic feel were used as main qualities which varied among the four concepts. Furthermore, the four concepts were related to the previously defined personas with the first concept targeted towards Signe, second and third towards Valter and the fourth towards Mats. Concept differentiation was referred to the battery being placed in different positions, resulting in differences mostly in riding quality and general ease of use. Also, the concepts presented different possibilities towards feature implementation since they used variable supporting structures.

Figure 33. Four initial concepts

The initial evaluation was performed at Chalmers university of Technology. The participants were master students in the industrial design department and their input towards theme and concept compliance was much appreciated. The total amount of participants reached a total of twenty students of both genders and age range from 24 to 32 years old. The evaluation was performed by introducing semantic differential scales for each bike. Four expressions 'Open', 'Simple', 'Dynamic', 'Robust' were used for evaluation. Furthermore, the evaluators pinpointed the one concept believed to be the most appropriate according to the theme.

The four concepts gave a very diverse responses probably due to them deviating from the prototypical features of a bicycle. The most appreciated were the ones resembling the bike the evaluation participants owned themselves despite the fact that some individual features were much appreciated. The openness of the frame was favorable as well as the shape of a "single frame" that was evident in concept three. Some remarks were made on the stability of the frame since in concept one seat stays were intentionally absent. The front mass of concept one and four were seen as top heavy and the sharp form evident in concept two and four was causing some thinking towards accidental injuries. Comments and remarks were noted and were used in the iteration session that followed.

During the second evaluation old aged people who belonged to the projects target group since they were presenting various mobility problems were asked to rate the concepts in the same manner as in the first evaluation (Figure 34). The total amount of participants was eight and it consisted out of both men and women in an age range from 62 to 74 years old.

Figure 34. Evaluation with target group

The evaluation with the target group did not produce the expected result. People from the target group are not used or trained in analyzing forms with the help of semantic differential scales. It was in the discussions about the different concepts that the interesting opinions were found. Not much related to the specific form but more general, like for example, towards the impression of structural reliability of the concepts. If the evaluation were to be remade it would probably be on a more general basis.

All feedback received was used to initiate a new form generation phase. The increased amount of information gained, required a structured approach throughout the form generating process. The process resulted after a series of creation, evaluation and iteration sessions into the project's final concept which will be presented in detail further in the report.

8.6 Form development process

As the structure of the bicycle; pedal, wheel, handlebar and seat were all set, the methodology found most relevant was that of functional surfaces (Tjalve, E 1979). This method uses something described as functional surfaces, areas in space that are already set in the design. The product is not only defined by its functional surfaces but from the areas required for its intended operation, something that is called banned areas. The pedelec under development consists of determined characteristics together with some banned areas due to pedal movement and the low step in frame. The functional surfaces and banned areas are defined as:

- Bicycle functionality. Areas and volumes needed to be kept free from obstruction due to functional elements requirement for space in order for the product to operate as intended. In addition, specific surfaces and areas needed to be connected in order to function as a bicycle.
- Ease of use related. Areas and volumes needed to be kept open to aid the functionality of the bicycle for the intended target group. *(Interpretation and translation from Tjalve, E 1979)*

This model fits the designing procedure of the bicycle since many of the elements are set as mentioned above, but the method is mostly focused on functional appliances and how their components are connected. To further incorporate the aesthetic form as an issue in the development process some parts of Wim Muller's "the fish trap method" were added. By using the fish trap method´s more form related ideation spurs, like typological factors and topological factors, the generating of form could, in an efficient way, be extended to aesthetics as well as functional. In the fish trap method, much like Tjalve also suggests, many concepts are generated in each stage of the generation of form and few, most promising concepts, are taken onto the next stage (Muller. W. 2001).

8.6.1 Quantifiable structure

As stated in the product qualities, features chapter 8.4 the quantifiable structure of the bicycle is set due to the behavioral characteristics of the bike such as fork angle, fork rake, wheelbase etc. (Tjalve, E. 1979). The next stage in the form development process is to define the functional surfaces, the places set in space that cannot be obstructed or changed (Tjalve, E. 1979), this to define the space available for the design of the bike. As seen below (Figure35) the different elements are ordered in the quantifiable structure as well as the functional surfaces and banned areas are visualized.

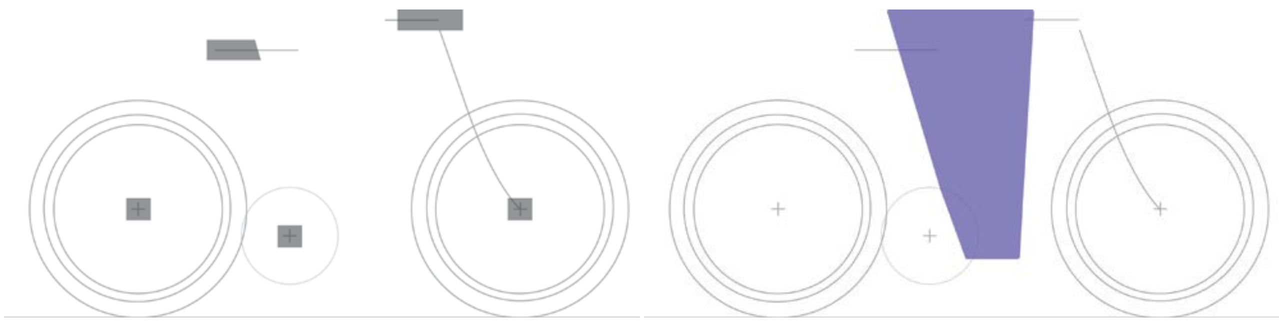


Figure 35. Definition of functional elements and banned areas (from left to right)

The next step was form generation, a stage which as described before is a diverging converging process. The three stages, topological, typological and morphological stage of the Wim Muller's fish trap method, results in a form development process seen in the figure below (Figure 36).

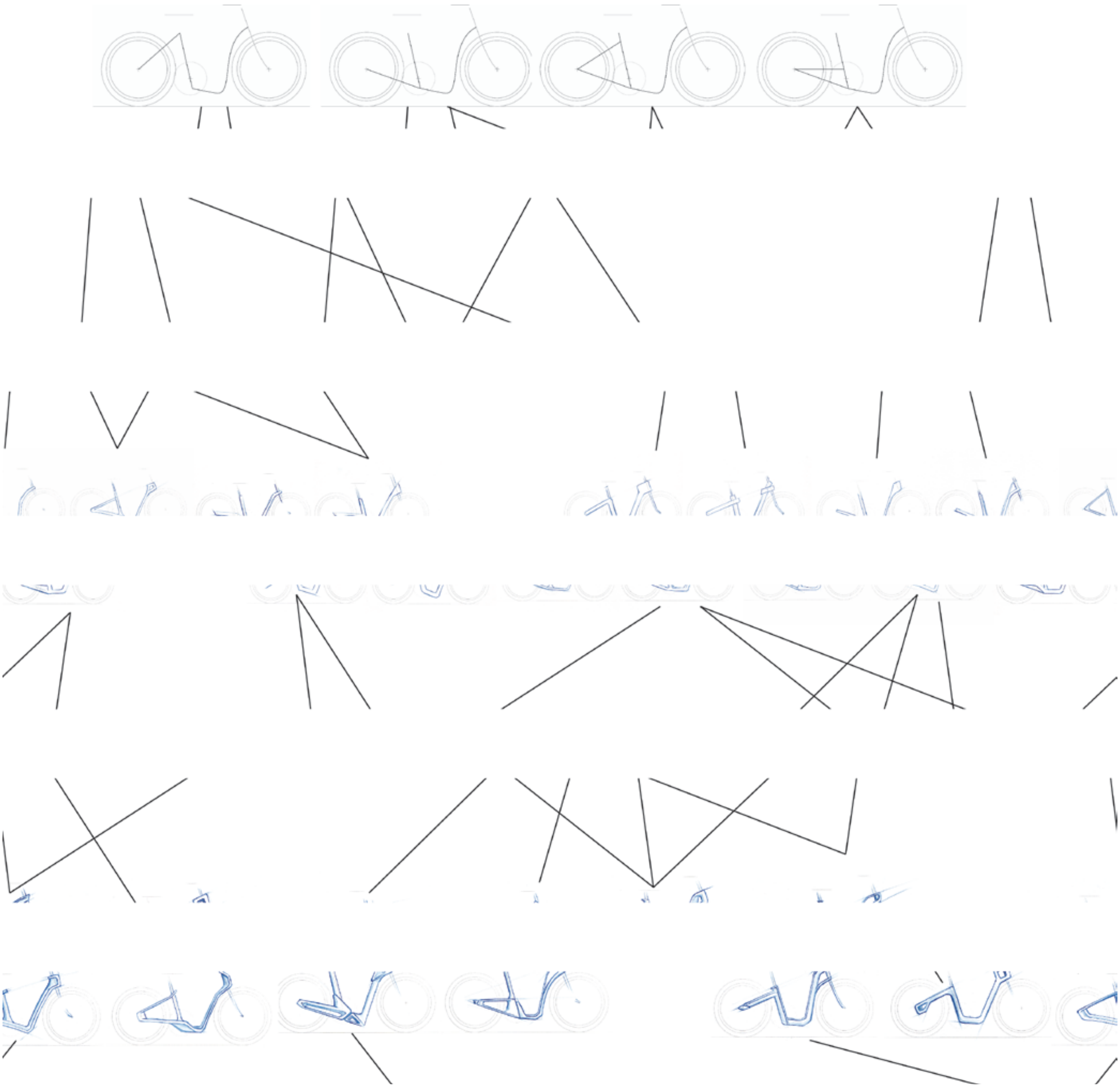


Figure 36. Fish trap method overview

8.6.2 Topological stage

As the structural concept is set in the quantifiable structure, the topological design ideation can take place. Using the Topological categorizations for design, linear, radial, orthogonal and centered according to the fish trap method (Muller, W. 2001), different configurations are found (Figure 37). The feasibility of the concept is not considered at this stage. The quantifiable structure is printed in low opacity on paper in order to make template to enable proportional sketches of the frame. The functional surfaces and the banned areas are not in the template since it would conflict the analysis of the frame design. The functional surfaces and banned areas were kept nearby when ideating to confirm validity of the sketch.

After ideating on the topological level, four ways of connecting the functional surfaces without obstructing the banned areas were found most interesting. They all fulfill the criteria of not obstructing the banned area as well as connecting the functional elements in an interesting way. The four topological concepts are called S, W,Triangle and Straight, in that order, due to their shape.

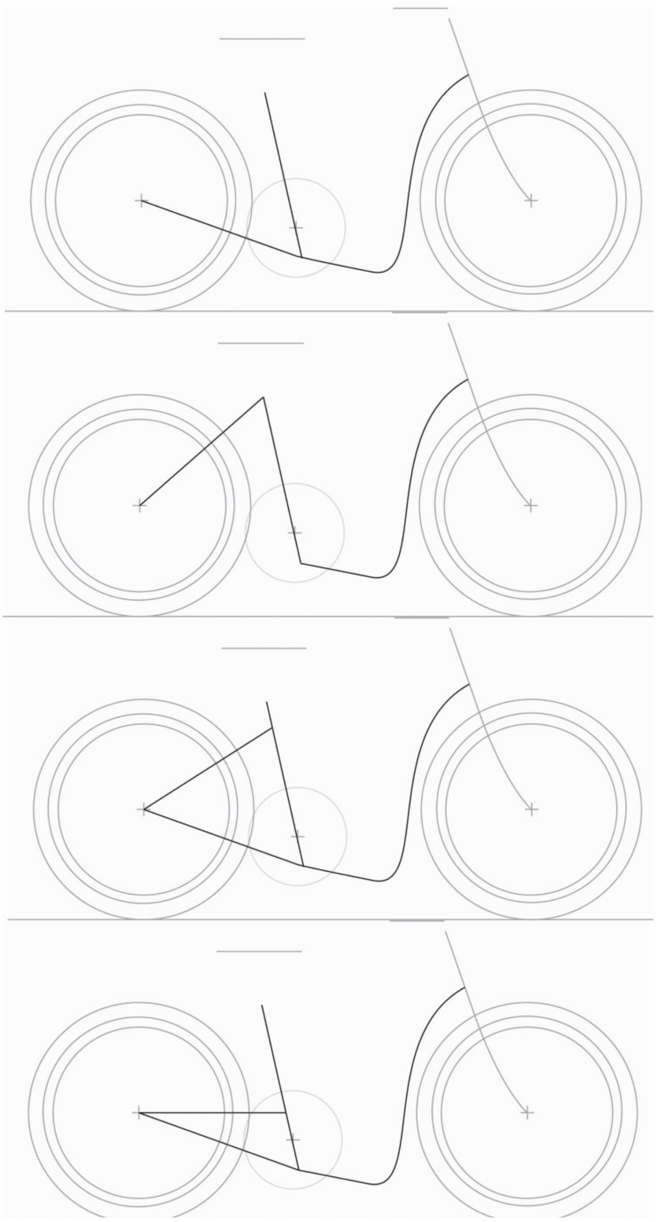


Figure 37. Topological ideation

8.6.3 Typological stage

The topological variants are chosen for further development with a typological focus. Working with geometrical forms, with dimensional, additive and subtractive techniques and with composite versus integrated forms according to the fish trap method(Muller, W. 2001), as well as Tjalve's variation parameters(Tjalve, E. 1979), the concepts are evolved (Figure 38). From the theme, the form drivers are busier in this stage, affecting the shapes and not just placement of the parts but the form of them as well. The number of concepts again increases in numbers, here the evaluation with the target group and the feasibility of the concept is involved when choosing which concept to develop in the next stage of the process. If the concepts were not deemed feasible at this stage it was either altered or sorted out. Some of the parameters used to ideate in this stage were profile thickness, varying thickness, and relations between geometries, composite versus integrated and top heavy versus bottom dominant.

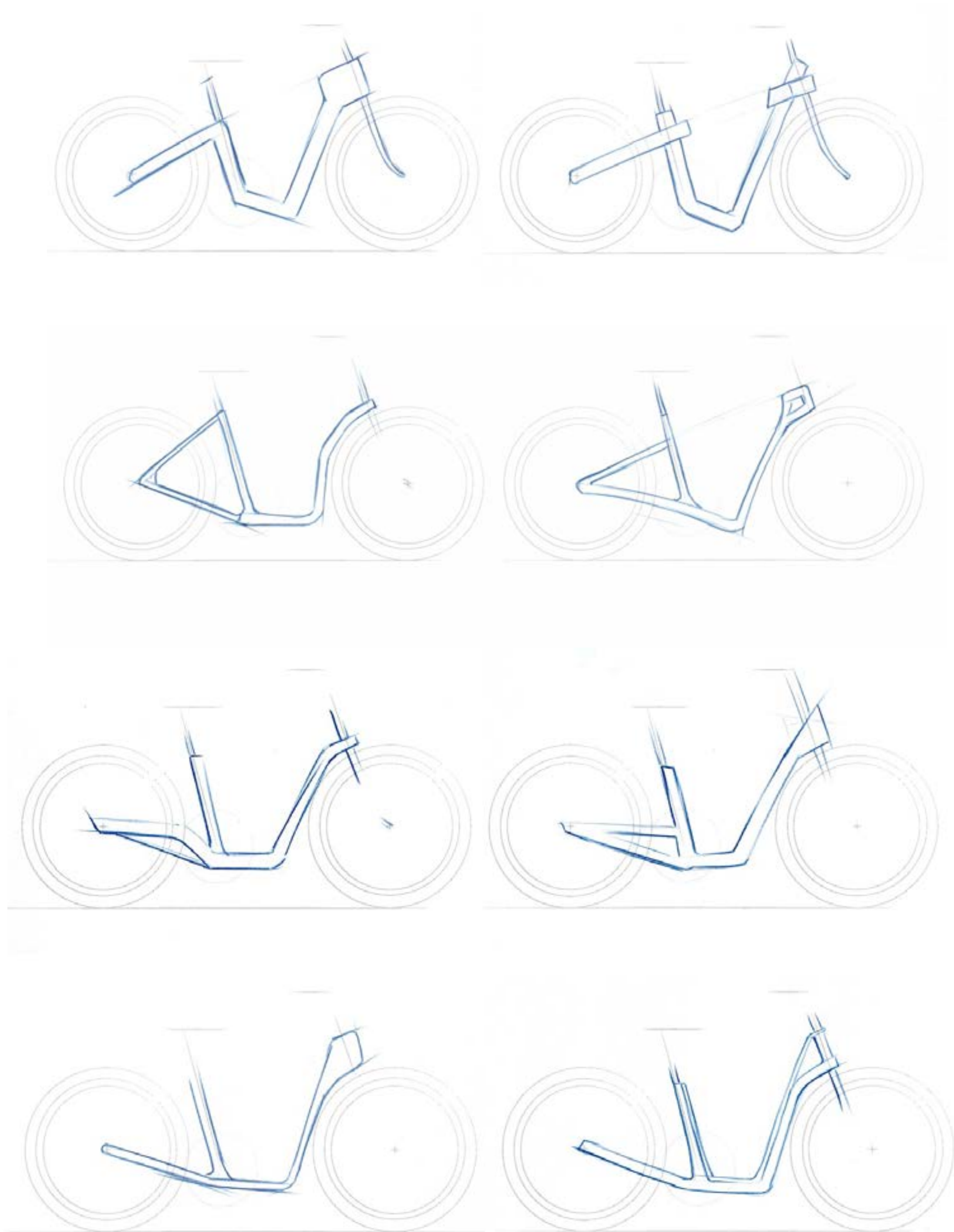


Figure 38. Typological ideation

In the evaluation with the target group and colleagues the S-frame was considered either unstable or heavy due to the imagined lack of stability. Even if it could be seen as the one fulfilling the simplicity the most, it was not considered as an option for further form exploration. In the evaluation, some concepts were deemed top heavy due to a large mass concentration in the steering tube area and therefore these new concepts have less mass high up. The form drivers are affecting the design in this stage with use of accelerating lines, dynamic feel, open frame characteristics and robustness.

8.6.4 Morphological stage

In the morphological stage manufacturing, material and specific solutions are further developed from the typological stage. Here not only the form is of interest but also functionality, solutions and materials are considered. Colors or textures were not added before this stage and this is the stage where they are introduced. Still, they are put on a minimum so they would not conflict with the form and that is the reason why the colors and textures are added just where it is needed to enhance the understanding of material and form. In this stage the sketching takes the step from two dimensions to three dimensions to better see the relation between parts as well as the functionality and feasibility of the solution.

The six concepts presented are variants of the typological step and some are a direct form from the topological step whilst, some are modified of combined from the topological step.

The concepts are named C1 to C6 in the following analysis. The analysis consists of a Design Format Analysis to see how well the concepts fulfill the theme. There is a scale assessing the extent in which the word from the theme is fulfilled, no relation, weak relation and strong relation(Figure39). The three different relations give zero, one and three points in the total score of the concept. How well the design of the bike fulfills the expression is decided by the project members as the designers. This evaluation is subjective and is used as a control and guidance in the design process. The result of the evaluation will be considered as a guide in choosing an appropriate design for the final concept.

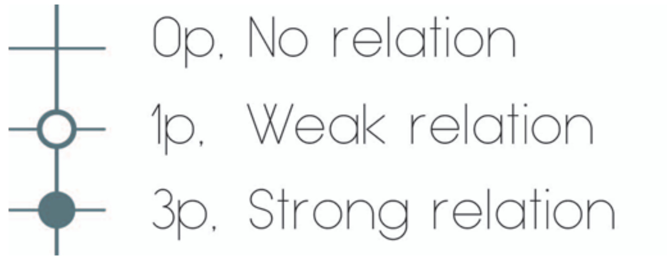


Figure 39. Format analysis scale

The six concepts were analyzed in the design format analysis and two concepts had an interesting rating, concept C2 and C3 as seen in the figure below (Figure 40).

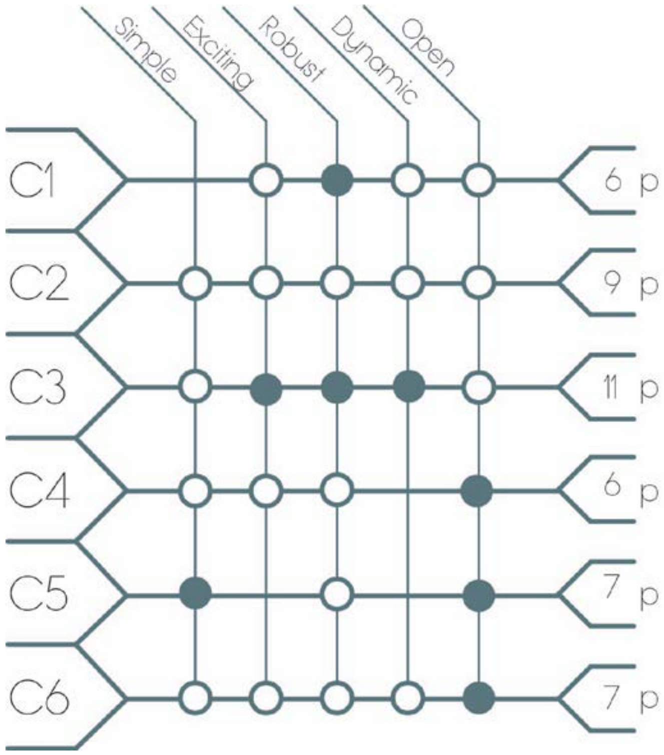


Figure 40. Design format analysis

Concept C1 is inspired by the S as well as the Straight shape from the topological stage and has a composite form with open spaces in the frame itself. It was assessed as capable but was deemed as to complex and bulky for further development.

C2 comes from the Straight topology and has, as C1, a composite form. The openness in the frame both rear and front is assessed as promising features even though the rear is slightly dominant over the front. It is slightly complex and needs further development if it shall be considered interesting.

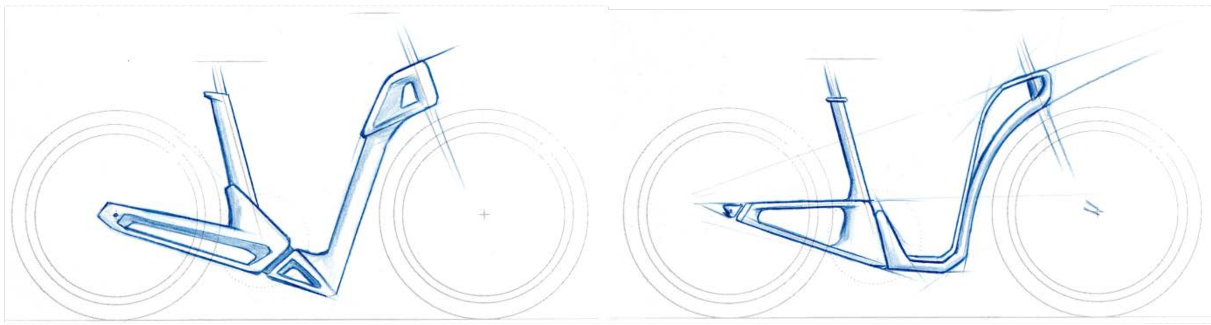


Figure 41. C1 and C2 concepts (from left to right)

C3 receives the highest score, meaning that it has the strongest relation to the theme according to the design format analysis. The only thing it is lacking is openness for entering the frame and it is slightly complex with its angles and changes in direction in the profile making up the frame. The clear direction of movement is what gives the dynamic score with the accelerating lines, this coupled with robustness gives a quite exciting expression. This concept will be further developed.
C4 is considered one of the most open with the small mass in the front as well as the slight bend of the profile connecting the chain stay and the seat stay. The very open frame also contributed to a slightly

less robust impression. The many bends and turns in the frame also made it more complex and the somewhat static look gave a low dynamic and exciting score. This concept will not be developed further.

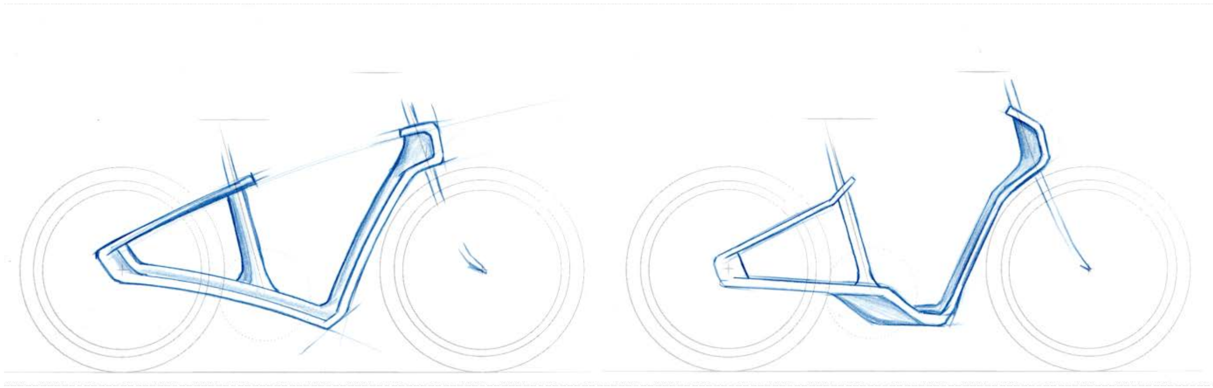


Figure 42.C3 and C4concepts (from left to right)

Concept C5 is deemed to be the most simple and open of the six concepts but not fulfilling any of the exciting or dynamic demands and it will be not a sample for further development. The design might also be a bit too playful for the sought expression and might be more appropriate for a much younger target group if developed further in the playful and simple direction.

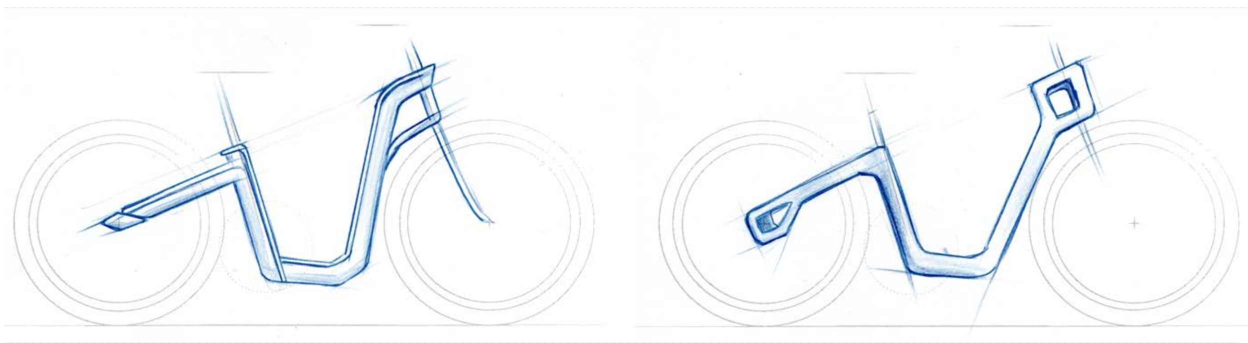


Figure 43.C5 and C6concepts (from left to right)

The last of the morphological concepts, C6 is a continuation of the W-shaped topological concepts. With a quite consistent rating of weak relations to the theme it will neither be developed further. Some parts are interesting for the project as the open front end. The openness is like the previous concept quite high but with an addition of complexity.

The quantifiable structure narrowed the development process effectively and is not seen as a limitation in the process. The following fish trap method worked well with the quantifiable structure as well, generating many proposals with more reliable results than it would without the quantifiable structure. The form development process using the fish trap method is sometimes a long and cumbersome procedure with many dead ends in design proposals. From the total amount of design proposals, only a small selection is showcased in the report. A form development process does need time as well for ideas to grow and designs to be synergized into final ideas. For this purpose the fish trap method keeps the designer in the process for a period of time slowly developing ideas which will be combined and discarded until the final design is archived.

8.7 Computer modeling

After completing the form generative process two forms were found to be most interesting. Concept C3 and a combination of concept C5 and C1 were modeled in three dimensions with the help of a CAD program(Figure 44,45). Small changes were made to see and explore more design possibilities. The two concepts were compared and concept C3 was decided to go forward with due to the capable and exciting design compromising with simplicity.

Figure 44. 3D evaluation modeling of combined C5 and C1

Figure 45. 3D evaluation modeling of C3 concept

8.8 The final design

Figure46. Final concept

The concept C3 is chosen because of its expression of capability, excitement and clear direction aiding the dynamic feel. It was also favored because of the natural integration of a light in the front of the profile encapsulating the steering column. The top also contains the electronics needed for the intelligent systems which aid the rider's situation awareness. The rear triangle is incorporated into the design as that was a concern in the evaluation with the target group, since without it the bike would be considered as not stable enough.

For the final concept, C3 was refined and evolved some more.

- The front tube connecting the bottom bracket with the steering tube was given a steeper angle to give more room to the user when entering the bike.
- The front upper part has a greater angle towards the ground both for achieving a more dynamic expression but also to direct the head light onto the ground since it is integrated into the frame's profile.

Figure 47. Final concept features and components

The different features found in the ideation phase are now incorporated into the final bicycle design. The indicators are incorporated in the handlebar at the end of each grip, no 1 in figure 47. The indicators are visible from the front, side and rear of the bike due to their placement on the end of the handlebar and the rear rack. Behind the flat surface at the front side of the steering tube a light source has been incorporated, no 2 in figure 47.The bell and the strobe light giving a signal when using the bell are also accommodated in the same place. This is to communicate to others in traffic the bicycle's presence. The concept not only communicates the environment to the rider but also the rider to the environment.

The battery is placed behind the seat post and is integrated in the design, no 6 in figure 47. The battery can be taken off the bike to be charged but preferably it is charged via an induction coil in the bottom of the frame, no 5 in figure 47. The battery can be taken out and charged if no induction charging is available. Placing the battery here gives a low center of gravity and it can be comfortably reached when removing it from the bike.

Disk brakes are fitted because of its functionality and capability, no 3 in figure 47. A Pedelec is heavier than a conventional bike due to the extra equipment so disk brakes present a good choice in breaking equipment. When breaking by doing a back pedal movement the breaking force created by the pedelecs hydraulic pump is distributed via a hydraulic system to the rear and front wheel. This resembles the system of a car and the rider needs only to interact with the brakes at one place, the foot pedals, not having brake leavers on the handlebar. By doing so, constant grip of the handle bar is achieved. Instead of having a chain guard mounted on the outside of the frame the belt drive is incorporated in the frame. This makes the design more simple and clean. The belt not showing also indicates less maintenance and a more easy use of the bike. As an extra feature the rim has a color indication where the valves are so that the user can easily find it when refilling of the tires is needed.

Figure 48. Final concept features and components steering

On each side of the handlebar the buttons for the indicators are placed, no 8 in figure 48. They are placed just inside the grip for easy access with the thumb. Located just over the indicator button on the right side of the handlebar the bell-strobe button is located, no 9 in figure 48. On each side of the handlebar there are also directional speakers directed towards the driver's left and right ear respectively, no 9 in figure 48. The directional speaker will only be heard from the side which they are playing and can therefore be used to increase the situational awareness of the rider even more defining the side another cyclist is passing. Into the grips small vibrators exist, no 12 in figure 48, which also help the rider's situation awareness by vibrating when specific events in the environment are triggered. The handle vibration is also connected to a seat vibrator which is activated first if someone is passing from behind. The vibration moves to the side of the handlebar that the other rider is overtaking.

Below the handlebar there is a screen where the rider chooses intensity of assistance and program the bike. This screen will not include advanced setting because it should not be manipulated when riding as well as the Pedelec is supposed to be as simple as possible to use and operate.

Figure 49. Final concept features and components rear

On the rear rack LED-lights are incorporated to function as brake lights and turn indicators, no 13 in figure 49.

Inside the seat post a hydraulic system is placed which lowers the rider when speed is significantly reduced and/or reaching to a full stop. This enables the rider to set their feet down before coming to a halt since users as well as the testing with the Gert suit, indicated balance problems on those situations. The cranks are shorter than those on a conventional bicycle to reduce the movement of stiff joints. Since the product has pedaling assistance from the electric motor the efficiency is not an issue.

Figure 50. Final design frame

The frame is made out of an extrusion tubular hydro form process allowing complex shapes and a hollow profile. The final design reflects the theme in a satisfactory way. The accelerating lines, clear direction and dynamic feel makes the product both capable and exciting. The single loop frame reflects simplicity with its low component count, as well as it gives a clean and uncomplicated form.

Figure 51.Front and non drive side view

Figure 52. Drive side and rear view

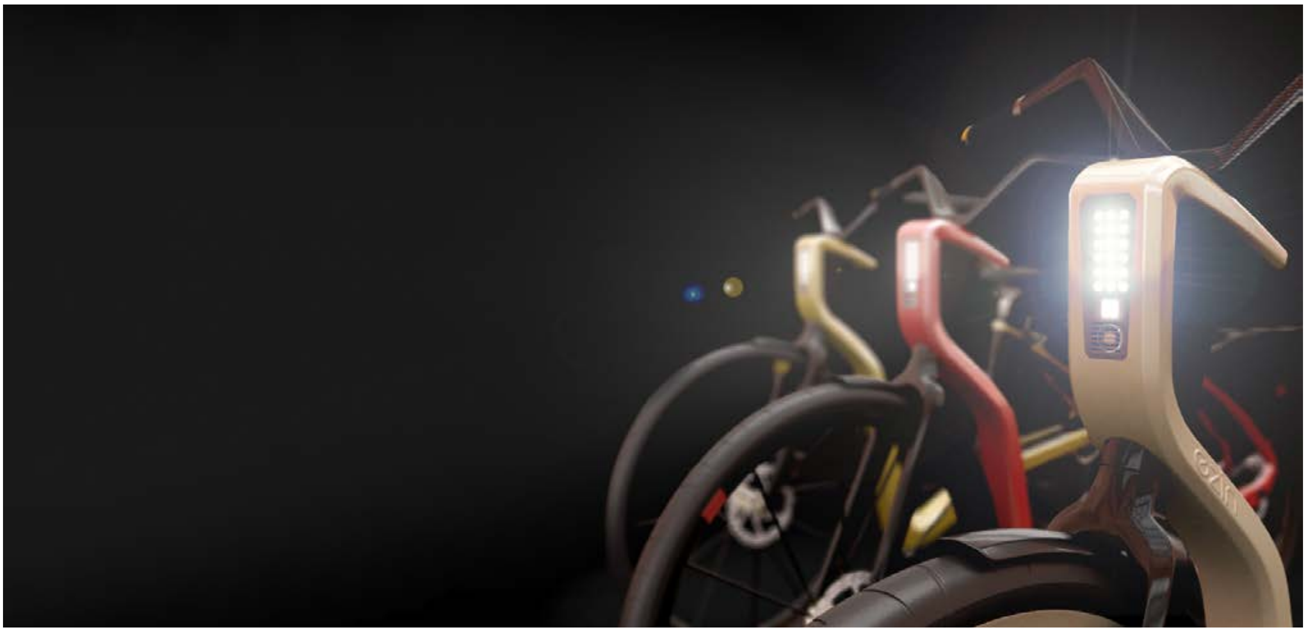


Figure53. Color variation

9 Discussion

9.1 Final result

The product presented does, with its functions, help the user with age related impairments to overcome some of the impairments that hinder them from using the bike. The bike accommodated the needs of the user as well as delivered more comfort because of the functions incorporated into the product. In addition, the desired expression from the theme is well incorporated in the final design. The bicycle has been around for a very long time as stated in the pre-study and the look for a bike is quite set in people’s minds. The aesthetic design of the bike was therefore the most difficult in the project since the evaluation with the target group revealed a reluctance to accept design other than conventional. To make a novel design with the right expression presented difficulties since the design should appeal to the target group as well as being interesting for the designer.

Since the project was made without the interest of a commercial partner the process was very free and unlimited. This led to a situation where all areas surrounding bicycles were available for investigation. As a result, a difficulty to find a focus for the project was evident. Having an industrial interest in a project makes it more focused, although not always for the better. In this project specifically, it could have led to an even more developed final concept and a more concentrated study due to the obvious inputs in material and manufacturing technologies from the industrial partner's part. The expert knowledge has been much appreciated from Cycleurope AB but it came in a late stage during the project when many decisions already were made.

In addition, along with the effort to keep a simple expression in the product form the implemented product features were also kept as simple as possible. By doing so, it does not mean that the product became less complicated when compared to a conventional bicycle rather than the features are based on an intuitive and straightforward implementation. Additional testing is needed to determine fine details and settings as well as the amount of automation that needs to be incorporated in the product.

9.2 Execution

As explained in the report the method chosen for the project was the ViP or vision in product design. The method deals well with future scenarios and products and works in a methodological way to the point of a new product. In the case of this project the product that was to be developed was predetermined, something obstructing the method's approach. This was well understood before the initiation of the project and the method was used as explained in chapter 1.5 “Project and report outline”. This made for some struggles in the process as the ViP works with a very open mind towards possible solutions and not with a specific product in mind from the beginning.

The aesthetic design of the bike also posed difficulties. The target group had a large influence on the project and the bike is a very user centered product. For the aesthetics though, it is difficult for users to describe what they like and find good looking, while often what they like is what they know. Here, the designer’s role to find a thrilling, novel and exciting design is put to the test. The method chosen for this was a theme made up of words to use as a compass in the process. To generate designs a quantitative method was used to get many possible solutions. Although the compass was there, knowing when a good design was found still was difficult to establish. The ultimate test if a design is right is when it is put on the market competing with others.

In order to design such a user centered product as a bicycle made to aid impaired persons, discussions and interviews need to take place as it has in this project. The target group was found to be very difficult to reach and ask questions. The questions themselves also need to be very well tested before so that the right information can be elicited and therefore pilot interviews were made. This resulted in that many of the potential interviewees were used for pilots and were not included in the final interviews which lead to a time consuming process looking for people to interview. Also a questionnaire was written and handed out but low response frequencies lead to that this could not be used for the thesis.

9.3 Future scenario

The future has got a large part of this project for natural causes. The future is a difficult thing to define since it depends on many factors. The future in this thesis both technologically and societal has been taken to a reasonable stage. It could be made in a more visionary way using solutions and scenarios that are much different from today. The choice was made to keep the future much like today with the changes that could be anticipated and were deemed as reasonable and probable. The focus was on the target group and not the possibility to design a futuristic product which incorporated all the latest technology, the latest materials and manufacturing techniques. The product is not meant to be a conceptual product which exists only on promises of the future.

A question was raised during the project about the future of the Pedelec. When the bicycle was fitted with a combustion engine it eventually turned in to what we call a motorcycle today. The question was if the Pedelec will follow the same path in the future, changing from being an electrically assisted bicycle to its own branch in the two wheeled transportation segment disconnected from conventional bicycles. It is an issue that will be clear in the near future.

9.4 Market introduction

Many aspects of the product are possible to make today even if the scenario is in a near future. By making some changes to the design it can accommodate today's technology and still be a highly functioning product according to the project members. The battery technology is near to completion but is not on the market yet, therefore a conventional Lithium-Ion would be fitted. This is possible to fit in the same place as the concept's placement behind the seat tube although it would need some design changes since it is larger in volume. The same goes for the hydraulic braking system, there are no such systems available on bikes today and either it could be made as a crude version without ABS and back pedal sensor or it would need much focus for development. A system with conventional brakes which just distributes the braking power in an appropriate way could also be a solution in using a single point of interaction for braking.

The frame is made with tubular hydro forming technique which would be possible today. The manufacturing technique has a high threshold with high initial cost and needs quite large volumes in order to achieve a reasonable final product cost. Since the target group is increasing and will be larger in some years maybe some parts of the bike can be manufactured with other techniques. This would impose further design changes and the expression of the product could be lost or changed.

The directional speaker is a technology which is on the rise and needs further investigation in order to be incorporated. In discussion with expert at Piteå interaction institute the directional speaker could be changed to a “much” directed speaker. This is a speaker which uses a conventional system with directional sound but needs more room in the handlebar making it chunky or too large and heavy to incorporate.

The ease of use related features could be made without further testing other than functionality testing. The traffic awareness systems need further thorough testing even though they fulfill the theory of helping in a traffic situation. Because of the critical nature of the traffic situation the systems need to be tested and tuned so that it helps the rider and doesn’t confuse or overload with information.

10. Conclusions

The project has ended up with a product offering people with age related impairment a mean for individual transportation which is made to make them more comfortable in a traffic situation. By using a multimodal system communicating events in the environment and the processing of impression can be made parallel, and thereby faster, to a greater extent.

The design of the bike is made to communicate the functionality of the bike by being exciting, capable and simple. The frame is a low step in frame making entering the bike easier and minimizing joint movement. The cranks of the bike are made shorter also to minimize joint movement, for the comfort of the rider. By stripping the bike of most of its outside cables and hiding a rather maintenance free belt drive inside the frame it gives a less complex impression. The motor and battery are placed low in the frame giving the bike a low center of gravity making balancing of the bike easier. By integrating a heart rate detector and linking it to the power assist of the electrical motor the bike can be used for exercising and rehabilitation causes, establishing a stronger user connection with the bicycle.

Some of the functions fit different disabilities better than others. Not all younger old and older old have a problem stepping through the frame and not all have trouble hearing and analyzing the traffic situation. The concept could therefore be sensitive for some people feeling that it is too much of an aid and not a capable transportation mean as intended. Therefore it might be a good idea having a choice in what aids the user needs on their Pedelec.

Working with a future context with all its components such as demographics changes, infrastructure changes and technological progression, makes valid projections of the future difficult. The need for information from leading experts has been difficult and there are some areas that are uncertain such as battery technology and infrastructural changes.

The product is a prototypical concept in need for much work before all functions are verified as fully functional. In theory the functions fulfill the needs of the intended user but a traffic situation can be complex and the systems need to be tested and probably fine-tuned before used in a real situation. A traffic situation is an environment consisting of many critical decisions and the different systems need to be tested and evaluated thoroughly before being implemented. The systems need to make the rider more aware in the situation but not being fully dependent on a system to handle a traffic situation.

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Glossary

Bicycle related definitions

Bottom bracket. The part of the frame around which the pedal cranks revolve
Chain stay. The part used in most frames that runs from the bottom bracket to the rear hub area
Compression of morbidity. The burden of lifetime illness may be compressed into a shorter period before the time of the person's death, if the age of onset of the first chronic infirmity can be postponed
Crank/Crank arm. The element which connects the pedal to the bottom bracket axle
Head tube. The front (usually tubular) element of the frame, through which the steerer passes.
Seat stay. The part used in most frames that runs from the rear hub area up to the seat tube
Seat tube. The frame (usually tubular) element running from the bottom bracket up to the seat cluster.
GERT suit. Abbreviation for GERontological Test suit. Set of apparel and accessories used for simulating older persons impairments

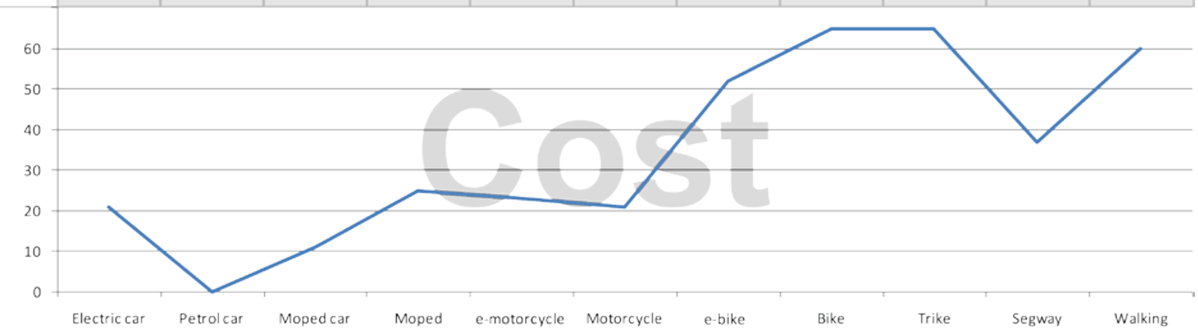
General definitions

Older-old . Person older than 75 years of age (Kroemer, K 2006, see Fisk et al. 2004)
Pedelec. Abbreviation for PEdal ELectric Cycle. A bicycle where the rider's pedaling is assisted by a small electric motor
Riding posture. The way a user positions the body while using a bicycle
ViP. Abbreviation for Vision in Product design. Design approach that supports the designers vision underlying their final design
Younger-old. Person that is 60-75 years of age (Kroemer, K 2006, see Fisk et al. 2004)

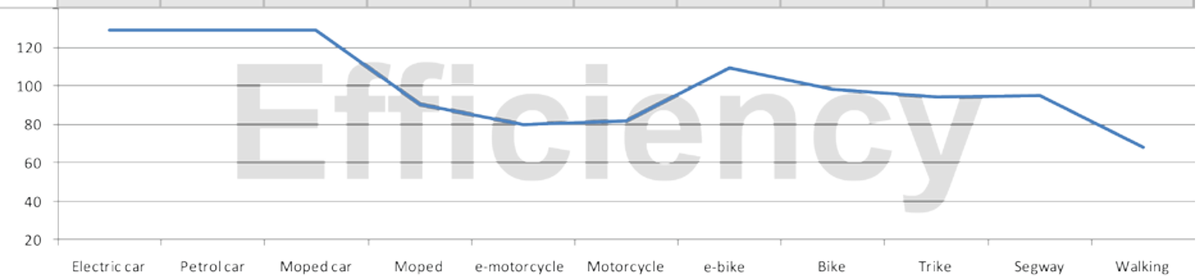
Appendices

Appendix A1 - Comparison charts

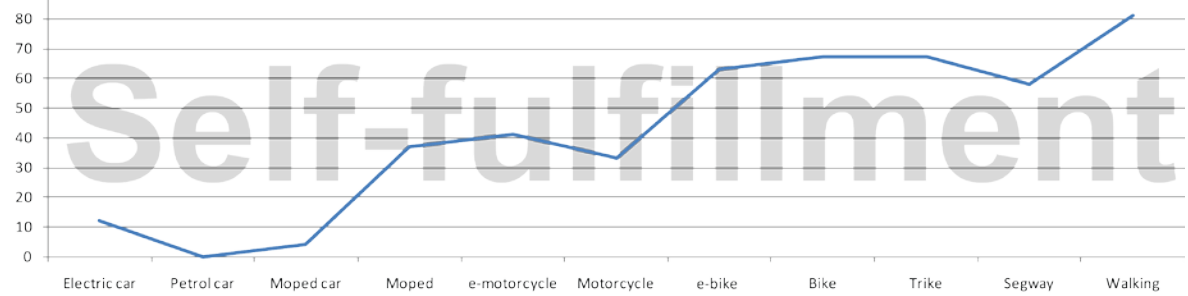
	WEIGHT	Electric car	Petrol car	Moped car	Moped	e-motorcycle	Motorcycle	e-bike	Bike	Trike	Segway	Walking
ACQUISITION COST SAVE	2	3	0	1	5	1	3	5	7	7	2	9
MAINTENANCE FREE	3	2	0	2	3	3	3	6	8	8	5	9
MILEAGE EFFICENCY	3	3	0	1	2	4	2	8	9	9	6	5
TOTAL		21	0	11	25	23	21	52	65	65	37	60



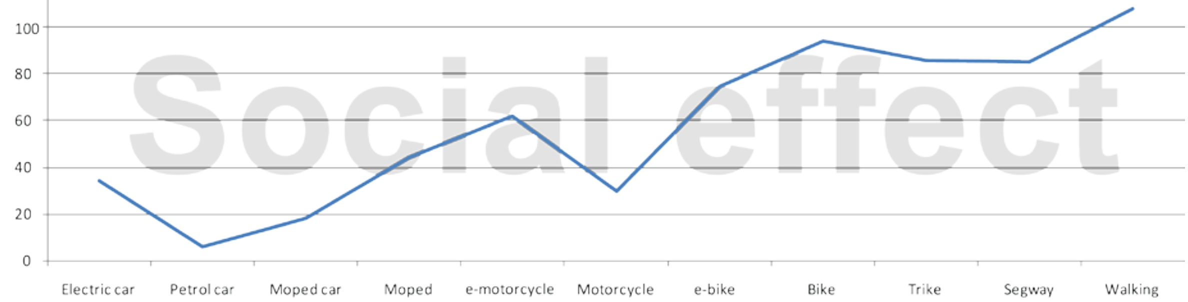
	WEIGHT	Electric car	Petrol car	Moped car	Moped	e-motorcycle	Motorcycle	e-bike	Bike	Trike	Segway	Walking
WEATHER PROTECTION	3	9	9	9	5	5	5	9	9	9	7	7
TRAFFIC SAFETY	5	7	7	8	4	1	1	8	8	8	8	9
RANGE	2	7	7	6	7	8	9	5	4	3	3	1
EFFORTLESS	3	9	9	9	9	9	9	7	5	4	7	0
CARGO	2	9	9	8	4	4	4	3	2	3	2	0
SPEED	1	8	8	7	6	9	9	5	4	3	3	0
TOTAL		129	129	129	90	80	82	109	98	94	95	68



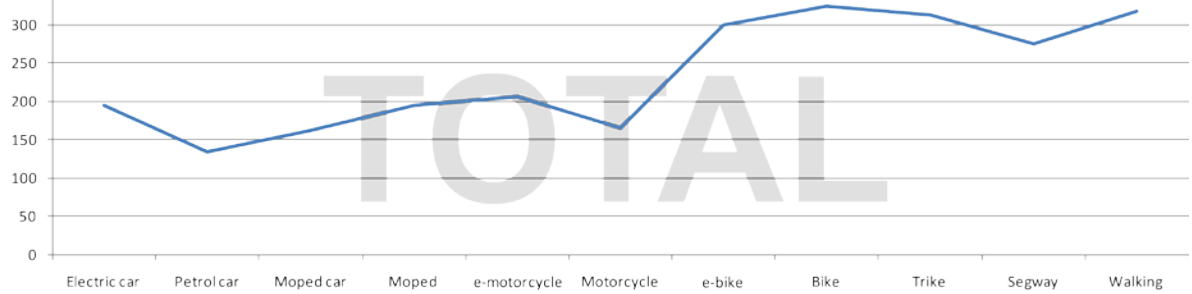
	WEIGHT	Electric car	Petrol car	Moped car	Moped	e-motorcycle	Motorcycle	e-bike	Bike	Trike	Segway	Walking
FREEDOM	5	0	0	0	5	5	5	7	7	7	8	9
SUSTAINAB...	4	3	0	1	3	4	2	7	8	8	7	9
TOTAL		12	0	4	37	41	33	63	67	67	58	81



	WEIGHT	Electric car	Petrol car	Moped car	Moped	e-motorcycle	Motorcycle	e-bike	Bike	Trike	Segway	Walking
SILENT	3	3	2	1	0	4	0	6	7	7	6	9
LOW EMISSIONS	5	5	0	3	4	6	2	7	9	9	7	9
SPACE EFFICENCY	4	0	0	0	6	5	5	7	7	5	8	9
TOTAL	4	34	6	18	44	62	30	75	94	86	85	108



	Electric car	Petrol car	Moped car	Moped	e-motorcycle	Motorcycle	e-bike	Bike	Trike	Segway	Walking
SOCIAL EFFECT	34	6	18	44	62	30	75	94	86	85	108
EFFICIENCY	129	129	129	90	80	82	109	98	94	95	68
COST	21	0	11	25	23	21	52	65	65	37	60
SELF FULFILLMENT	12	0	4	37	41	33	63	67	67	58	81
TOTAL	196	135	162	196	206	166	299	324	312	275	317



B

Appendix A2 - Retailer interview sheet

Retailer interview.. Address .... Date ....../......./..........

"The future electrically assisted bicycle for an ever aging population"

People are getting older and generally getting more active around and after their retirement time. Also, today's jobs more than ever before effect people in negative ways by introducing a passive physical behaviour for long time periods. Bicycling is a good way of getting that needed exercising time which can be combined with everyday transportation among others providing even more advantages. Some disadvantages of bicycle usage do exist but they can be overcomed with the help of an electric pedal assisting generator. The electric bicycle helps to overcome obstacles like difficult uphills and sweaty long distances when transporting compared to conventional bikes. In addition electricaly assisted bicycles provide the possibility to carry more cargo. The e-bike appeals to a larger part of the market with its advantages.

We are concerned regarding the future of transportation in relation to using a bicycle.

1. Basic client characteristics. What do they seek in a bicycle? How does that change with the type of bicycle that they are looking for buying (quality, price, performance, reliability, local or international brand preference)

2. Is there a difference between swedish and international bicycle brands towards quality, service costs and aesthetics.

3. Basic characteristics related to weather. infrustructure, retailers, chain stores, taxes, licences

4. Which is the most popular type of pedelec? (commuter, mountain, foldable, hybrid)

5. Buying a pedelec is considered by most as a purchase of a leisure activity bicycle or as a personal trasportation vehicle (one and only solution for transport)?

6. Do people prefer pedelecs that look like conventional bicycles or more like electrical ones?

7. Is there a difference in the types of bicycles that different age groups are buying? Any specifics towards elderly people? What do they prefer? Which are the features that they are considering when choosing.

8. Peak seasons, is there any interest at all during winter times?

9. Do you consider that pedelec buyers are more in need of support, service from their retailer comparing to a normal bicycle

10. Opinion regarding Kronan, Crescent, Skeppshults,, Monark, Ecoride and other brands and which is the most SWEDISH bike

11. What type of accesories do people buy? Are they different comparing ebikes and normal bike owners?

12. Average amount of money spend on bicycles/ebikes?

13. Is owning an electrical bike more expensive comparing to a conventional bike other than buying it?

Don't forget to say "Thank you..."

A3 - Future context factors

Developments

The demographic will shift in proportion to a larger percentage of people over 60 years of age, up by 9% till 2040 making 31 % of the population

The percentage of people above 60 suffering from chronic age related problems will be less due to the compression of morbidity

The maintenance of the bike paths will be higher, especially wintertime since more people are using their pedelecs all year round

Increase in sustainability awareness

Induction charging is getting more explored and evlodev in car industry and mobile appliences

Solar power is evolving and implemented on a bike today

Battery technology is evolving constantly and in the future it is safe to assume the battery being half as big/heavy and having twice the capacity compared with today's lithium-ion batteries

Distance traveled with pedelec is higher than conventional bike

When owning a pedelec people use it more than they would use a conventional bike

The price paid for pedelecs is considered probable to rise in future

States

The target group have stiffer joints making joint movements limited

The target group experience a decrease of muscular power due to atrophy

The target group have a slower reaction speed due to residue in the nerve cell connections

Getting old leads to feeling more disconnected from the bike

The price people pay for their pedelecs is higher abroad

Principles

Charging outlets in these parking places shall be accommodated so the commuter can charge their battery when the bike is parked

The roads should be more straight and wider and smooth since more people will travel and at higher speeds

Better parking possibilities and weather protection at parking shall be provided

Pedelecs are more expensive and therefore safekeeping is more important since the value of the product increases

Trends

People are getting more educated about the electrical system on the pedelecs

Buying over the internet will be more common

The production and sales of bikes in general are increasing

As the numbers of sold pedelecs increase so does the stores selling them. More Hyperstores like Biltema, XXL, Coop will sell cheap ones

People buying pedelecs are more prone to treat it like a car, asking for service plan at retailers

People want their pedelecs to look more like conventional bikes because electrical parts scare them

Increase of percentage of pedelec over conventional

The price people pay for their second pedelec is much higher than the average

Many people buying pedelecs are not used to biking because they have been driving a car for commuting

Future

Authorized pedelec service workshops in the future

The pedelec is acknowledged as a good exercising tool for cardio and fat burning

A4 - SWOT

S

Reduce physical effort
Increase commuting range
Carry more cargo
Increased average speed
Increased added features
Physically impaired users

W

Increased part number
Fast worn brakes
Battery performance is weather dependant
Heavy
Aesthetic disruptions
Cost of battery replacement
Conventional use is not optimal

"Strengths, Weaknesses, Opportunities and Threats"

O

Integrate heavier features
Implement electric and electronic features
Developments in battery technology
The best current alternative in dense traffic situations and sustainability

T

Public transportation becomes more accessible
Electrical cars get more agile, less expensive
Efforts are not spent on bicycling infrastructure

A5 - Focus group findings

SAFETY	EASE OF USE	FEATURES
Setting max velocity	Segway mode bike	Turn signals
Feeling close to the ground	Smooth (steering, balance, acceleration, braking)	Combined signaling Brake-Stop light Ring - Flashing front light
Handle airbag	Getting on and off easy	Mirrors
Improve balance	Handling the bike when not using it	Blind spot sensors
Slip proof tires	Not too futuristic	Haptic feedback to contact points
	Not actively addressed to old people	Speaker, microphone integrated in cockpit (intercom, headset, navigation, situation notification)
	Extra support in slow speeds	Rotating saddle
	Cargo carrying ability	Self adjusting saddle height (in relation to speed)
		USB charging option
		Remote control
		Electric lock

A6 - Product qualities list evaluation

			COG effect	Improve situation awareness	Higher level of Automation	Weight decrease	Reduce visual complexity	Eliminate geometric constrains	Ease of use	Physical control	Cost Decrease	SUM
Ease of use	1	Centered motor	3	0	0	0	-1	-1	1	1	-3	0
	2	Automated gears within the motor	0	1	3	0	3	2	2	0	-1	10
	3	Low step in frame	2	2	0	-1	0	-2	3	1	-1	4
	4	26" Wheels	1	0	0	1	0	1	1	1	1	6
	5	Increased bottom bracket drop	3	0	0	0	0	0	1	1	0	5
	6	Reduced crank length	2	0	0	1	0	1	1	0	0	5
	7	Fork trail and offset values used for commuting	0	1	0	0	0	-1	1	2	0	3
	8	Back pedal electronic braking	0	2	3	-1	3	0	3	2	-1	11
	9	Regenerative energy function	0	0	2	0	0	0	2	0	-1	3
	10	Inductive charging	0	0	3	0	1	0	3	0	-1	6
	11	Belt drive	0	1	0	1	0	0	2	0	0	4
	12	Self balancing mechanism	0	1	3	-3	-1	-1	3	3	-3	2
	35	Turn indicators	0	3	0	-1	-1	0	0	0	-1	0
	36	Rear view mirrors	-1	3	0	-1	-3	-1	2	0	-1	-2
	37	Rotating saddle	0	1	0	0	0	0	1	0	-1	1
	38	Usb charging option	0	0	1	0	-1	0	3	0	-1	2
	39	Remote control	0	0	3	-1	0	0	3	0	-2	3
	40	Electric lock	0	0	3	-2	0	0	3	0	-2	2
	15	Cargo carrying ability	-3	0	0	-3	-3	-2	3	-1	-1	-10
	16	Additional support in lower speeds	-2	1	3	-3	-2	-2	3	3	-2	-1
	17	Integrated battery inside the frame	1	0	0	0	3	-3	0	0	-2	-1
	18	Battery level indicator	0	1	1	0	-1	0	1	0	-2	0
Situation awareness	20	Automatically adjusted saddle height regulated by speed	-1	1	3	-1	-1	-1	3	2	-1	4
	21	Option for adjusting pedaling assistance in relation to physical condition (heart rate monitoring, breath frequency…)	0	0	3	-1	1	-1	2	1	-1	4
	22	Combined wheel braking with Antilock Braking System (ABS)	0	0	3	-1	0	-1	3	3	-1	6
	23	Integrated front and rear lights	-1	3	3	-1	-1	0	3	0	-1	5
	24	Combined auditory and visual signaling	0	3	3	-1	0	-1	3	0	-1	6
	25	Proximity tactile signaling	0	3	3	-2	0	-1	2	0	-2	3
	26	Directional speaker use	0	3	3	-1	0	-1	2	0	-2	4
	27	Turn indication and brake lighting operated with concave capacitive switches and back pedal brake	0	3	3	1	2	-1	3	0	-2	9
	28	Brake lights operated automatically with back pedal brake use	0	3	3	-1	0	0	3	0	-1	7
Safety	29	Setting maximum velocity	0	3	3	-1	-1	-1	3	0	-1	5
	31	Handle airbag	-1	0	3	-2	-1	-1	0	0	-2	-4
	33	Slip proof tyres	0	0	0	0	0	0	0	1	-1	0
		Sum	4	33	49	-20	-2	-16	63	19	-36	

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